

# JOURNAL OF ANIMAL BEHAVIOR

VOL. 1.

JULY-AUGUST, 1911.

No. 4.

## HABITS AND REACTIONS OF THE CILIATE, LACRYMARIA

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EIGHT FIGURES

### INTRODUCTION

Lacrymaria is among the most interesting of living beings owing primarily to its phenomenal power of elongation, its wonderful elasticity and its great freedom of movement.

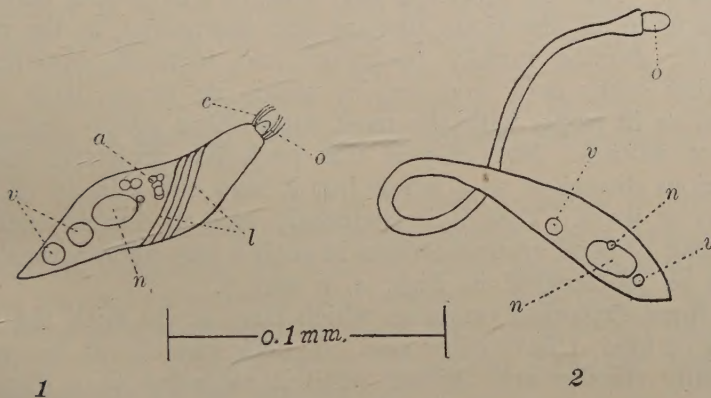


FIGURE 1—Camera sketch of a living specimen of *Lacrymaria*. v. contractile vacuoles; n. macronucleus; n'. micronucleus; c. oral cilia; o. oral knob; a. symbiotic algae; l. lines showing arrangement of the body cilia; mm. projected scale.

FIGURE 2—Camera sketch of an individual with the neck partially extended; cilia not represented. This specimen was killed with Worcester's fluid for protozoa. I found it impossible to kill these creatures without marked contraction of the neck.

It is a spindle shaped ciliate about 0.1 mm. long and 0.02 mm. in diameter. At one end there is a knob-like projection on which the mouth is situated. This projection is bordered

at the base by a band of large powerful cilia. The rest of the surface of the creature is sparsely covered with cilia which are relatively long but very delicate. The knob-like protuberance containing the mouth, and the adjoining tissue containing the band of oral cilia will be referred to as the head, and the tissue immediately back of it as the neck. Fig. 1.

#### HABITS

Specimens of *Lacrymaria* are relatively scarce in nature. They are occasionally found in cultures containing decaying aquatic plants but never in great numbers. One rarely finds more than two or three in a drop of solution. They usually appear in the debris which collects at the surface of the water, and under the microscope are found well concealed among fibrous algae and masses of various other substances which constitute the debris. Hidden away thus they frequently remain in a given place for many minutes practically motionless with the exception of the anterior end, the end containing the head and neck. This end stretches out, often to a surprising distance and turns in all directions, upward and downward, to the right and left, darting rapidly backward and forward, apparently exploring every nook and crevice within its reach, back of it as well as in front, with the most astonishing agility and freedom of motion. Not only is this neck-like proboscis turned in various directions as a whole but it may curve in an endless variety of ways. Thus it is frequently seen to double back on itself and to bend around objects in such a way as to form sharp angles as represented in Figs. 4, 6 and 7.

In these exploring reactions which have to do with the procuring of food, I have often seen the neck stretch out, becoming gradually thinner and thinner until it extended to a distance equal to eight times the length of the body and was but little larger in diameter than one of the oral cilia. We often marvel at the length of the neck of the giraffe and the freedom of movement of its head and are baffled in attempting to explain how in the process of evolution it came to be what it is. And yet the neck of this animal is scarcely as long as its body. If it were relatively as extensible as that of *Lacrymaria* we would find the giraffe browsing leaves from the tops of trees well toward one hundred feet in height, and if it were relatively



as free in its movements we might see it thread in and out among the branches, selecting choice morsels from any part of towering monarchs of the forest and stripping them of their foliage.

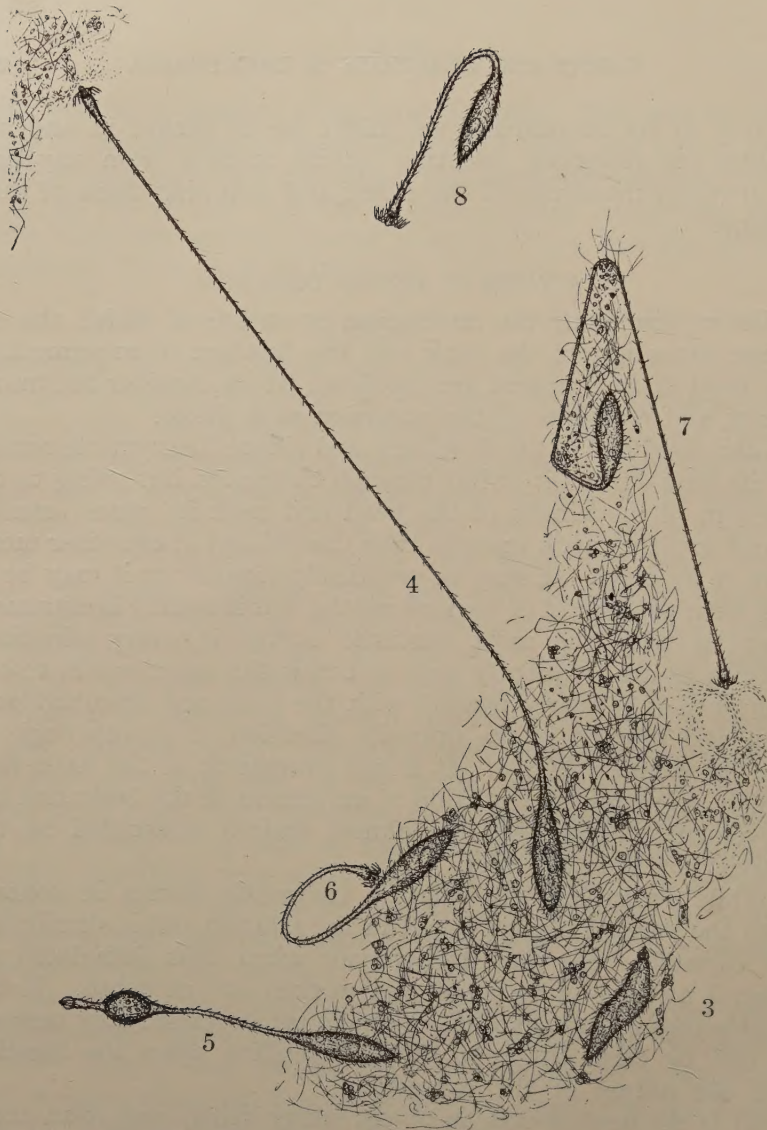
#### REACTIONS OF ENTIRE ORGANISM

Before discussing the mechanism by means of which the extreme extension of the neck and the freedom of movement of the head of *Lacrymaria* are regulated let us consider the movements and reactions of the organism as a whole.

Like nearly all of the flagellates and ciliates *Lacrymaria* rotates on its long axis as it swims through the water, but owing to the freedom of movement of the head and neck its course usually varies greatly, much more so than that of any of the other members of its class. It may be practically straight or it may be in the form of a spiral of various widths, but it usually is extremely irregular with the most fantastic curves in every direction. Specimens are frequently seen to throw the anterior end to one side until it is nearly parallel with the body and then suddenly turn and proceed in the opposite direction or at any angle to the old course. Fig. 8. It is the movement of the head that largely regulates the direction of movement of the body and the movements of the head are almost entirely controlled by the activity of the oral cilia.

While swimming the creature frequently comes in contact with the various objects found in the solution and is stimulated. By carefully observing its behavior when thus stimulated its general method of response was worked out in detail. If the head comes in contact with an object the organism may respond in two or three different ways, depending upon the location and the nature of the contact.

(a) If the head strikes an object rather lightly and at an acute angle the animal usually deviates from its course only enough to slide by and avoid the obstruction. Thus specimens may be seen to glide about through the interstices of a fibrous mass turning in various directions without any apparent response. The change in the direction of motion under such conditions appears to be due entirely to the mechanical effect of the object on the moving organism. It may be, however, that the oral cilia are directly stimulated by the contact and respond in such a way



- FIGURE 3—*Lacrymaria* at rest. The debris in which it is concealed consists largely of small filamentous and unicellular algae. Note the oral cilia folded over the oral knob which contains the mouth. The cilia are much more numerous than represented. The small circles represent contractile vacuoles, the globular body the macronucleus.
- FIGURE 4—A specimen with the neck fully extended. The dots in front of the creature represent particles carried toward the mouth in a current produced by the oral cilia.
- FIGURE 5—An individual shortly after having swallowed a small protozoan which is still lodged in the neck.
- FIGURE 6—A sketch showing the neck bent on itself and the head in contact with the body over which it passes apparently cleaning the surface.
- FIGURE 7—An illustration of the manner in which the neck is often bent so as to form sharp angles.
- FIGURE 8—A free swimming specimen suddenly changing its direction of locomotion by turning the head and neck sharply toward one side.



that when the side of the head strikes an object the cilia on that side become more active and force it in the opposite direction.

(b) If the anterior end comes in contact with an object more directly the animal usually stops and either contracts the neck sharply, turns it toward one side and proceeds in a different direction or reverses and swims backward, frequently for a considerable time, especially if the stimulus is the result of an injury. If the posterior end strikes an object in swimming backward the creature immediately reverses again and swims forward.

By means of a very fine glass rod I was able to stimulate specimens which were at rest or swimming slowly at any desired point and it was also possible by this means to vary the strength of the stimulus. In this way numerous attempts were made to ascertain more precisely the relation between the reaction and the location of the stimulus. The results of these observations together with those described above show very clearly that the response in *Lacrymaria* is somewhat dependent upon the part of the body stimulated. When the anterior portion of the animal is touched it frequently swims backward, whereas I was never able to induce this reaction by stimulating the posterior portion either in animals that were at rest or in those that were swimming slowly. There is consequently in this creature a differential response to a localised stimulus in a restricted sense. A given stimulus applied to the anterior end causes a response different from that caused by the same stimulus applied to the posterior end. Further than this I was however unable to demonstrate that the response depends upon the location of the stimulus. If the head is stimulated the neck usually contracts, then turns toward one side and extends in a different direction as already stated, but the direction in which it turns bears no observable relation to the location of the stimulus on the head. After being stimulated at a given point the head may turn either toward or from this point or in any other direction. The direction of turning under such conditions seems to be regulated entirely by internal factors. The same is true with reference to *Paramecium*, *Euglena* and many other similar organisms. In these organisms, however, the direction of turning is restricted by a structural or physiological differentiation of the body. They always turn toward a given side. *Paramecium*, e. g., as Jennings has clearly shown, always turns toward the aboral side and *Euglena* toward the

larger lip. *Lacrymaria* on the other hand is not thus restricted in the direction of turning; it can turn toward any side. This does not mean that the direction in which this animal turns is not definitely determined; it merely means that the determining factors are within the organism. There are also other reactions in *Lacrymaria* which are clearly dependent upon internal factors. As a matter of fact, without any immediate environmental change whatever the oral cilia may become quiet or active, or when striking backward they may all suddenly reverse and strike forward causing the head to move backward, or only those on one side may reverse, causing the head to move sidewise. Thus it is evident that it is possible to predict the reaction of *Lacrymaria* only in a very general way. Its movements are largely in accord with the generally accepted definition of random movements. It avoids objects and finds food by trial, which means merely that the direction in which the animal moves is not definitely related to the location of external objects, sources of stimuli, and that successive different axial positions are taken until the animal succeeds in avoiding obstructions or in procuring food.

We assume that all of these reactions are specifically associated with physico-chemical phenomena in an orderly way, or to put it in a more popular form, that they are mechanically regulated. But for all that is known to the contrary, psychic phenomena may be involved as is undoubtedly true with reference to certain trial reactions in the human being, although the relation between these reactions and the psychic phenomena is not well understood. I shall refer to this question again under regulation of the movements of the head.

There is no indication of orientation in *Lacrymaria*, nothing in the nature of a tropism as defined by Loeb (1906, p. 135, see Mast, 1911, pp. 54, 23-35), except perhaps in an electric current in which the reactions have not been studied.

#### FEEDING

*Lacrymaria* ordinarily obtain their food by capturing and swallowing small unicellular organisms. Occasionally, however, specimens are found that obtain a certain amount of food from a small globular plant which they contain, an alga. Some specimens contain only a few of these minute plants while others are



well filled with them. These plants in their life processes use waste products formed by the animals in which they live and in turn form substances of which the animals make use as food, that is they are symbiotic. They are not merely temporarily located in the animals, but live in them generation after generation. This is shown by the following facts:

(1) A number of *Lacrymaria* were isolated and examined from time to time for several days. In these and in numerous other specimens examined at different times but not isolated all of the algae found were at all times bright green, indicating that they were alive and not undergoing digestion. (2) No similar algae were found free in the solution. (3) The algae found in *Lacrymaria* are identical, both in size and structure, with those found in *Paramecium bursaria*, an organism in which they are known to be symbiotic.

These algae are nearly spherical in form, contain three or four relatively large chloroplasts and have a diameter about one-seventh the width of *Lacrymaria*. How the algae get into and become fixed in these creatures I am unable to say, but it is likely that they are symbiotic in unicellular forms which are taken in as food. At any rate, these ciliates in all probability feed on organisms which sometimes contain algae.

Only four specimens of *Lacrymaria* were seen in the act of feeding, and in only two cases was it certain that the food was actually alive, although it probably was in all. The process of seizing an object and engulfing it is so rapid that it is very difficult to be certain as to its nature. In two of the four cases observed the object swallowed was probably an ameba. In the third it was a small globular ciliate, apparently *Halteria*; and in the fourth it was a flagellate, probably *Chilomonas*. In one instance the substance swallowed had a volume fully equal to that of *Lacrymaria*. This mass was engulfed with surprising rapidity, but it passed slowly down the neck which was distended to a size fully equal to or a little larger than that of the body. The mass finally lodged in the anterior end of the body nearly doubling its length. The ciliate was engulfed in less than a second, but it required fully fifteen seconds to pass down through the neck which was bulged out much like the neck of an ostrich in swallowing an orange. The diameter of the ciliate was nearly three-fourths the width of the body of the lacry-

marian and even after it was apparently in the body it was carried out with the neck a considerable distance whenever the head was fully extended (see fig. 5).

The securing of food in *Lacrymaria* is strictly on the trial basis. There can be no question but that it has the power of selection in this matter. Inorganic particles are never swallowed. The body of these animals is usually well concealed in debris as already stated, and the anterior end is stretched out in every direction, sometimes to a distance equal to eight times the length of the body and every nook and crevice within this radius is explored. During this process the head is repeatedly extended, jerked back and turned in different directions in rapid succession, giving the appearance of a most active, nervous and exciting search very much like the movements of *Didinium* (Mast, 1909, p. 96). A strong current clearly seen in solutions having particles in suspension is produced by the action of the powerful oral cilia. This current, especially prominent when the body is fixed, no doubt brings the mouth in close contact with various objects which would otherwise be only lightly touched or escape entirely in the searching movements. Thus it is clearly seen that many particles are tested and a few selected. Indeed, in no protozoan is the power of selection of food more evident than it is in this creature with perhaps the exception of *Didinium* (Mast, 1909, p. 113). As far as I could ascertain it swallows no inorganic matter at all. Specimens were repeatedly kept from one to forty-eight hours in solutions containing carmine or Chinese ink finely ground, but in no instance were any of these particles found in the animals. Moreover, they evidently also have the ability to discriminate between different living organisms of the same size or nearly so, for I have frequently seen many organisms rejected which were plenty small enough for them to swallow. As to the mechanism of selection in this protozoan we are entirely in the dark. Our evidence does not even warrant a conclusion as to whether it is on the basis of chemical or tactile stimuli. However, but little more is known regarding the process of selection of food in other unicellular forms, although Schaeffer (1909, p. 889) thinks that his observations show that the selection of food in *Stentor* is dependent upon tactile stimulation and not upon chemical.



## CLEANING REACTION

One frequently sees specimens of *Lacrymaria* with the neck extended and curved on itself so as to bring the head in contact with the body over which it passes back and forth lengthwise occasionally several times in succession but usually only once or twice. Fig. 6. The rapid movement of the oral cilia during this process makes it appear as though the surface of the body were being thoroughly cleaned. It is, however, probable that in this reaction the head is merely running over the body as it would over any other object under similar circumstances.

## REGULATION OF THE MOVEMENTS OF THE HEAD

The center of interest in the activities of *Lacrymaria* lies in the movements of the head. How is it possible for an organism to extend its neck in all directions eight times the length of the body, fifty times its own length, and while thus extended to turn the head rapidly and extensively in all directions, making curves and sharp angles in the neck, bending it on itself and the like, and then to contract the whole so that it disappears almost entirely in the body? Figs. 3-8.

It has generally been assumed that the anterior end of *Lacrymaria* is forced out by a sort of peristaltic circular contraction of the tissue in the neck and that its lateral movement is produced by unequal longitudinal tension on opposite sides, that the movements of the neck and head are regulated much as are those of the tentacles of *Hydra* or those of an attached *Stentor* on its stalk. This, however, is in all probability not true. In the first place it seems impossible that circular contraction could force tissue out to such an extreme distance compared with the diameter of the organ involved and at the same time admit of such free lateral movements as are found in this animal. And in the second place, to account for the formation of sharp angles in the neck with the tissue on either side of the angle straight as represented in Fig. 7, it must be assumed that unequal tension exists only between the body and the place where the angle is formed, and that the neck beyond the angle is rigid enough to swing the head from side to side without bending, a condition which seems quite impossible. We must consequently look elsewhere for an explanation of the phenomena in question.

In teasing with needles the debris in which *Lacrymaria* are found, one occasionally tears off the anterior end of specimens and thus accidentally performs an operation which would otherwise be exceedingly difficult owing to the small size of the creatures and their constant motion. The movement of four pieces thus torn off were studied in detail. One of these pieces consisted of the head and a portion of the neck about as long as the body, another was torn off immediately back of the band of oral cilia and the other two were between these in length. They lived and were active from three to five minutes. The reactions in all were essentially the same. They swam about rapidly, stopped, turned freely and sharply in any direction; in short, the movements and responses of these detached segments were strikingly similar to those of the head while still attached to the body. The only essential difference to be seen is that after stimulation there is very little if any backward movement of the detached heads, whereas, in the attached heads under like conditions, it will be remembered, there is marked backward movement. This indicates that the extension and the lateral movements of the anterior end in *Lacrymaria* are regulated principally by the activities of the oral cilia, that this end is not thrust out, but pulled out, not swung from side to side by unequal tension of symmetrically situated tissues in the neck, but pushed from side to side by the action of the cilia; and that the principal function of the elastic tissue in the neck is to draw the head back by contraction. These ideas are further supported by the following observations:

(1) In specimens with the head cut off immediately back of the oral cilia the neck is extended only a little and moves but slightly from side to side, although they swim about freely, forward and backward much like normal specimens. In fission the oral cilia of the posterior individual do not develop until some time after separation takes place. Thus we have two individuals, the anterior with oral cilia, the posterior without; and we find that while the neck of the former stretches out normally, that of the latter extends relatively but little. This indicates that while the neck can be thrust out somewhat by the action of internal tissue, the oral cilia are necessary for full extension.

(2) When *Lacrymaria* is free the neck rarely projects to a distance equal to twice the length of the body. It is only when



the body is lodged in debris or rests against some object that the anterior end is fully extended. It would thus seem that the body must be held in order that full extension of the neck may occur. While the neck stretches out under such conditions, it can often be seen that the body moves slightly forward as though it were straining the tangle which holds it, but as soon as the head stops or returns the body settles back to its original position again. I have repeatedly seen this when the cilia on the body were at rest. The forward movement must therefore have been due to a pull on the body from the anterior end. If the head were thrust out in place of pulled out, the body, provided the cilia on it be inactive, would move backward, while the head advances, in place of forward as was actually observed.

(3) The oral cilia are always active while the head is moving forward and quiet while it is moving backward. Many observations were made with reference to this and in every case it was found that the oral cilia become active simultaneously with the beginning of forward movement of the head and strike backward, but that as soon as the head starts to return they strike forward a few times and then fold in over the oral knob and remain quiet. When the head turns toward one side the cilia on the side toward which it turns strike forward and those on the opposite side strike backward. This was distinctly seen several times in detached heads. These observations show that the forward and lateral movements of the head may be due entirely to the activity of the oral cilia and that the backward movement is probably due to the contraction of the neck.

It is thus evident that the behavior of this animal is dominated to a very large extent by the activity of the oral cilia. Not only is the direction of locomotion of the entire animal regulated by them and the extension and the lateral movements controlled by their reactions, but they may also furnish much of the motive force in swimming. One often sees individuals swimming about with the body curved so as to form a hook which extends almost at right angles to the direction of locomotion, showing clearly that the body cilia are temporarily at least practically inactive and that the oral cilia alone are functional in producing forward movement, that the body is being pulled through the water by the action of these cilia,

for any effective action of the body cilia would, under the conditions mentioned, produce much greater sidewise movement than is observed.

Thus it may be assumed that the head of *Lacrymaria* behaves much like an independent organism attached to the body by means of highly elastic tissue, far more elastic than rubber of the best quality, for that can be stretched only eight to ten times its own length, while the neck of this creature can be extended approximately fifty times its length when contracted.

What has been said above regarding the explanation of the behavior of the entire organism applies also to the movements of the head, but there is one phenomenon observed in the latter that I wish to consider more in detail here.

It will be remembered that when the head of *Lacrymaria* turns toward a given side the oral cilia on that side strike forward while those on the opposite side strike backward. This difference in the action of these cilia is independent of the character and the location of the stimulus. As a matter of fact it occurs without any apparent external change whatever. It is therefore evident that the direction of turning in this animal must be determined by internal conditions. And this is true with reference to many other lower organisms. Some of these organisms, e. g., *Paramecium* and *Oxytricha*, are clearly asymmetrical and in these the direction of turning is associated with their structural asymmetry. Others, however, e. g., *Ædogonium* swarm-spores and *Didinium*, are like *Lacrymaria*, radially symmetrical. In these we find cilia somewhat similar to the oral cilia in *Lacrymaria* and in the process of turning the cilia of the former act just like those of the latter. But *Ædogonium* and *Didinium* like *Paramecium* and *Oxytricha* always turn toward the same side, and whenever they turn the same cilia strike forward, while those on the opposite side strike backward. To account for this it is only necessary to assume a fixed internal structural or physiological differentiation.

*Lacrymaria* on the other hand can turn toward any side. The same cilia are consequently not always involved in the forward stroke in the process of turning as is true for *Didinium* and *Ædogonium*. In this creature the oral cilia on any side may strike forward while those on the opposite side strike backward. To account for the change in the action of the different oral



cilia on a mechanical basis we must assume a corresponding change in structural or physiological differentiation in the tissue within the organism. The direction of turning cannot be accounted for on the assumption of a fixed differentiation as it can in *Didinium*, *Edogonium* and many other lower organisms. What this internal regulatory change consists of is a problem for further investigation.

#### REPRODUCTION

Lacrymaria reproduce by dividing crosswise near the middle into two parts. No apparent change takes place in the two ends of the dividing individual during the process of reproduction. The anterior end of the mother becomes the head and neck of one of the daughters and the opposite end becomes the posterior end of the other. The endoplasm continues to surge back and forth through the gradually decreasing opening between the daughters whenever there is a sharp turn or a contraction in either until but a short time before they separate, showing that this substance does not necessarily divide equally.

The activities and reactions of dividing individuals are essentially like those in individuals not dividing. The movements and reactions of both daughters, until they have actually separated, appear to be regulated almost entirely by the activities of the head and neck of the parent.

Lacrymaria like most of the other protozoa conjugate. Two individuals after having decreased in size until they are not more than half as long as ordinarily, come together and fuse temporarily at the oral ends with the necks stretched out to a length about equal to that of the body. While they are thus united they swim about actively, but there is no coordination in their movements as there is in conjugating *Paramecia*. Both individuals respond to stimuli independently. This leads to all sorts of fantastic movements. One frequently sees the bodies of the conjugating specimens following each other round and round in a circle, held on their course by the necks which extend to the center where they are united. Through these two long necks the nuclei must pass in the interchange of germinal substance preceding the process of fertilization. The regulation of the movement of the nuclei in travelling this comparatively great distance constitutes an interesting problem.

## SUMMARY

1. *Lacrymaria* has the power of most remarkable extension of the neck and freedom of movement of the head. The neck is sometimes stretched out to a distance equal to eight times the length of the body, about fifty times its own length, and while thus extended the head in rapid succession turns and moves in all directions exploring everything within this radius while the body, usually concealed in debris, remains quiet.

2. Detached heads perform all movements that attached ones do except the backward movement. Practically all of the movements except this one which is caused by the contraction of the neck, are due to the activity of the oral cilia.

3. The direction in which the head turns is in all probability regulated entirely by internal factors. It is independent of the location of the stimulus, although the contraction of the neck and the consequent backward movement of the head may not be.

4. The direction of locomotion of *Lacrymaria* in swimming is regulated almost entirely by the movements of the head. The head turns to the right and the left, upward and downward, frequently suddenly and sharply; the body follows the head on its tortuous course much as though they were organically independent and united merely by a highly elastic fibre.

5. Stimulation of the anterior end may not only cause contraction of the neck but also backward movement of the entire organism, while stimulation of the posterior end usually causes forward movement. This difference in reaction constitutes the only evidence of the dependence of the behavior of *Lacrymaria* upon the location of the stimulus. Practically all of the remaining reactions are in the nature of random or trial movements, movements which are determined largely by internal factors, the nature of which is as yet unknown.

6. There is no evidence of orientation in this organism and nothing in the nature of a tropism as defined by Loeb with the possible exception of its response to an electric current.

7. The food of *Lacrymaria*, except in the few specimens which contain symbiotic algae, probably consists entirely of unicellular organisms which are captured and swallowed alive. Some of these organisms are half as large as the creatures which swallow them.



8. The head in its jerky, rapid, random movements tests every object within reach and rejects all those which can not serve as food. It does not swallow inorganic substances, carmine or ink particles and the like. This protozoan unquestionably exercises selection in feeding. The mechanics involved in the process of selection are, however, not known.

9. During conjugation the reactions of the two united individuals are not coordinated. Each responds to stimuli independently.

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## NESTS AND NEST-BUILDING IN BIRDS: PART II

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EIGHT FIGURES

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4. Analysis of Increment Nests on the Basis of Behavior. Position of the Nest. Uniformity in Selection of Nesting Site. Do Birds in Nesting seek "the Protection of Man?" Individual Change in Nest Site. Size of the Nest. Double, Compound or Superimposed Nests. The Materials of Nests and their Method of Arrangement. Appropriation of Nest Materials illustrated.
5. Variations in the Nests of Certain Birds. Variation in the Red-eyed Vireo. Variation in the Wood Pewee. Variation in Hummingbirds' Nests.

The descriptive literature of birds' nests, which is extended to great length, is chiefly concerned with their size, position, and general environment, as well as with the kinds of material used in construction. When certain species are considered the recorded variations in respect to most of these characters are both numerous and striking.

The highest order of constructive effort exhibited by modern birds is embodied in the increment nests of either statant or pendent types. Thousands of species, many of which represent the highest existing order of Passeres build more or less elaborately after this general fashion, according to their specific modes.

We shall first attempt to give a general analysis of increment nests in order to ascertain their more uniform and more important characteristics from the standpoint of behavior, as well as to determine the significance of the variations to which they are subject. No pretense is made of offering more than a suggestive outline, for seldom has it happened that all the conditions under which a given nest was built were even approximately known.

#### 4. ANALYSIS OF INCREMENT NESTS ON THE BASIS OF BEHAVIOR

In considering the behavior characteristic of the builder in any species of birds, the following marks of the finished nest have special significance: (1) The form and dimensions of



the inner wall, or in other words the diameter, depth, and symmetry of the "cup,"<sup>20</sup> which are its most constant and valuable characters, especially in the statant nest; (2) The form and treatment of the outer wall which is characteristic of many nests of either type; (3) The arrangement of the materials used in construction, or the way in which they are put together, but it should be noted that our information under this head can never be reliable or complete without careful observations on the builders at work. These several characters are the most important marks of increment nests because the uniformity which they present in all individuals of a given species is very marked, being the result of uniform methods of building.

The following characters, with notable exceptions, are less constant because subject to a greater number of modifying influences; (4) The kind of materials used in construction, which are commonly variable, being as a rule drawn from the nearest source; (5) The size or weight of the nest, which is most constant in the pendent group, but subject to wide variation in nearly all which are supported from below, and (6) finally the position, which is notoriously subject to wide fluctuation in a great number of species. By "position" we mean the kind of support or immediate environment, as well as the point in space, in reference to the surface of the ground, which the nest occupies.

It will be most convenient to notice the several characters enumerated in inverse order, since the uniformity of the outer and inner walls will be illustrated by specific cases later. (See section 5.)

*Position of the nest.* We might say with a degree of truth that adequate support required for a nest in a given case is usually a prime factor in determining its position. To give an immediate illustration: the mourning dove (see fig. 1, part 1) commonly builds its shallow platform within 10 feet of the ground but at the present moment a pair of this species is occupying a nest at a height of nearly 40 feet. It is placed in the crotch of a maple tree, 15 feet from a house and above the level

<sup>20</sup> It is common to speak of the outer and inner surfaces of a nest as its "walls," which meet at the "rim;" the "inner wall" will often be designated the "cup." There is properly but one wall, the inner surface of which corresponds to the cup, when the word is used in this sense.

of its attic windows.<sup>21</sup> Now the interesting fact to notice in the case of these doves is that, as often happens, they used the remains of an old robin's nest as the foundation for their own. The presence of such a ready made support evoked in them the building responses, and it is safe to say that the old nest at that particular point and indeed in that particular tree determined the presence of the new one. We may add in passing that this nest was begun by the male on April 16, and finished by him on the following day; it was composed mainly of roots taken from a freshly dug trench close to the tree.

While certain species habitually nest high and others low, the question of vertical height is unimportant within limits. These limits, moreover, are determined by other habits and would be greater in high flying doves than in cuckoos, which keep closer to the ground. Unimportant too in many cases is the nature of the support, for we cannot credit the bird with man's concept of "natural," as distinguished from "artificial" structures.

While we appreciate the futility of drawing general conclusions upon most phases of this subject without taking refuge in the proviso that some species or individuals are likely to vary more and others less, we shall endeavor to consider the problem from the standpoint of the bird, and first in the case of the robin, the cuckoo, and the chimney swift.

The robin in nest-building looks primarily for a good support, that is *good* in both the physical and biological sense, or suitable in reference to its methods of construction and other habits; since such supports abound great variation in this respect is inevitable; now we find its nest close to the ground or even upon it, now in the crotch of a mere sapling or saddled to the high horizontal branch of an apple tree or elm. I have seen the robin nesting on the end of a stick which a farmer had set against his barn, on the stump of a tree recently felled, as well as against the protecting side of the corded wood to which a tree had been reduced; then it may build on a roof-gutter when it is liable to be disturbed by the householder, on a porch shelf, or on a neat bracket set against the wall of house or barn expressly for its use. Many such sites evoke in certain individual robins the same kind of response, and many are chosen in consequence.

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<sup>21</sup> For calling my attention to this nest I am indebted to Mrs. Robert Ruedy, of Cleveland Heights Village, Ohio.



Though such supports as the last named are good for robins, they would be very poor for cuckoos in relation to their feeding and other habits, and would never be taken. Such, moreover, might not appeal to certain robins, when the circumstances of their birth or experience had led them far from the haunts of man.

The black-billed cuckoo (*Coccyzus erythrophthalmus*) so far as I have observed in central New Hampshire builds only in sapling white pines, stunted crabs and thorn apple bushes, the total recorded variation in height of nest in this species for the entire country being only 16 feet (25 inches to 18 feet). This remarkable constancy in position, or as to height and immediate environment, is plainly determined by the habits of the birds when on their breeding and feeding grounds. We have only to recall the stealthy, stalking manner of life of this cuckoo, which keeps near to the ground, and inhabits pastures or brush grown places where such trees and shrubs as I have mentioned abound and afford the necessary support and concealment which are invariably sought; in such places also they secure their prey, and their young can climb about in comparative safety until ready for flight.

The swift of North America has been often cited as a remarkable example of a bird which has changed its nesting habits in recent times. Formerly breeding in hollow trees, and still doing so in remote places, it now regularly resorts to the abodes of man and glues its wicker nests (see fig. 8, part I) to the inside of chimneys. Both the barn and eaves swallows, and indeed many other species are in like case, but we cannot accept the view that the habits of any of these birds have essentially changed since the advent of white men to this continent three hundred years ago. The swift indeed, shows a remarkable uniformity and precision in its instincts which have remained unaffected by the presence of man, the boasted change referring merely to the position of the nest in artificial as distinguished from natural structures. These birds, like hundreds of others, come to the clearings and to towns for their food, and like them also, merely adapt the altered physical conditions to their established needs. Like the stork nesting on the housetop, or the osprey on the cart wheel set horizontally on a high pole, or indeed the purple martin or the bluebird, which take kindly to the house provided

for their exclusive use, they simply go where food abounds, and when not deterred by fear, fraternize with man to some extent.

The swift inherits the tendency to nest in a dark and cavernous place with free entrance and exit, and to its mind the chimney is a hollow tree with better ventilation in summer, but with poorer protection from rain than that which the forest supplies; but so far as the immediate environment goes its instinct is not quite precise or uniform, for the interior of a barn or of any dimly lighted building, where no interference is offered, may be chosen upon occasion. To conclude, so far as nesting and general habits go both swift and eaves swallow are remarkably constant, and far more so than either the robin or the song sparrow.

Certain phases of the question of position, especially in reference to the immediate environment will be considered at this point.

*Uniformity in the selection of nesting site.* That certain birds or their young, as in the case of the flicker or redheaded woodpecker, often return to the same nest site,—to the ancestral tree, bird house or box,—is adequately accounted for on the principle of association, and the proved tendency of the young to return to the place of birth. On the other hand certain species of birds, like the orioles and vireos choose their nesting sites with great uniformity; in our own minds we invariably associate the Baltimore oriole with the elm, the red-eyed vireo with maples, sapling pines with black-billed cuckoos, and tall evergreens with crows and many of the hawks. As in the other cases considered so far as the birds are concerned, the association is primarily due to the supports furnished by such trees in relation to the food and the habits of the species in question. The problem is precisely the same as in the robin, but with the field of choice greatly restricted. While I have seen hundreds of robins' nests in the apple, maple and elm trees, the number found in the poplar (*Populus tremuloides*), and gray birch (*Betula alba*) during a period of over twenty years, is not more than one or two in each instance, a fact which we should attribute to the lack of proper supports which they furnish, when the requirements of cover and other needs are completely met. The building robin makes an equally good choice, as we have seen, whether it takes to the pine, maple, apple, or oak, but the response of



the red-eyed vireo (see fig. 9) is limited to a much narrower range; its support must be a forked twig of not greater diameter than a lead pencil, and this fork must be fairly stiff, horizontal and of suitable angle; the various maples, whether as saplings or as larger trees, and the witch hazel in less degree furnish these conditions to perfection, while the pines seldom or never do; the former are consequently chosen wherever food abounds. The vertical height at which such a nest is placed is a matter of secondary importance from the standpoint of the bird, within the limits set by the whole trend of the habits of the species.

A long series of experiments on moving the nests of birds together with their supports, which are tabulated in an earlier work already referred to (see note No. 6, p. 161 of part I), illustrates a slightly different phase of the question. For a brief period the element of association appears to be sifted from the instincts, when a bluebird or cedar waxwing will immediately fly to the point in space formerly occupied by the nest, and hover there for a moment, following the old course which habit had marked out. This may be repeated several times and for the space of twenty minutes more or less, or until the young are heard or seen in their new position. When, however, these young are once found and visited the old habit is quickly lost, and a new one formed.

*Do birds in nesting seek the protection of man?* To follow the problem of position of the nest into another quarter, Nuttall<sup>22</sup> has remarked that the robin, in order to secure protection from its numerous enemies "has been known to build his nest within a few yards of the blacksmith's anvil; and in Portsmouth, New Hampshire, one was seen to employ for the same purpose the stern timbers of an unfinished vessel, in which the carpenters were constantly at work, the bird appearing by this adventurous association as if conscious of the protection of so singular and bold a situation." It is a pity to take all the poetry out of such agreeable suggestions, but in most cases at least the truth certainly lies in another direction.

Audubon<sup>23</sup> again speaks of finding a nest of the robin fastened

<sup>22</sup> Nuttall, Thomas. Ornithology of Eastern North America, vol. 1, p. 200, Boston, 1897.

<sup>23</sup> Audubon, John James. Ornithological Biography, vol. ii, p. 192. Edinburgh. 1834.

to the cribbing timbers of an unfinished well seven or eight feet below the surface, and of another which rested on a bare rock. It would surely be interesting to know whether the habit of nesting low, implied in these and similar cases which could be given would outlast the season, but on this point we can offer nothing at present.

The evidence that certain individual robins, swallows, or bluebirds seek the neighborhood of man or noisy situations for the protection thus secured, is probably delusive. As we have said, they come to places inhabited by man chiefly for food, and that they learn to endure noise and disturbance through association is not to be doubted. The protection thus gained is incidental, and wherever the domestic cat reigns it can be but slight at best, and certainly not greater than in a more primitive environment. In any case we should need to know the conditions under which the nest was started, for a robin or bluebird will begin to build about machinery or on the timbers of an unfinished dwelling when the workmen are away, with perhaps a quiet Sunday intervening, and then by instinct and by association hold to the chosen spot in spite of all ordinary obstacles. Many cases are constantly reported in which birds have chosen the most extraordinary and anomalous positions for their nests, the choice being possibly made under the conditions intimated. The following account will illustrate the class of nests to which I refer.

A bluebird's nest was discovered by workmen near my home in Cleveland Heights Village, Ohio, while engaged in taking down the framework of a sewer trench, on May 19, 1910; at this time it contained three young nearly able to fly. This singular nest was placed in a narrow pocket of the framing, and but a few feet from an overhead track, on which for weeks a line of suspended dumping cars had been running back and forth during working hours, and with what noise and jarring can be easily understood; for over a month besides it had been subjected to repeated danger from dynamite blasts which showered stones all about it from the trench below; meantime with the advancing work of construction it had travelled along the street for about the distance of a city block, and all the time close to the grinding racket of a steam engine with its screeching whistle, and to the laborers who, in operating their cars, passed directly under it.

Who would say that such untoward surroundings were deliberately sought for the protection afforded by man? In this instance a most unfavorable site was without doubt chosen on account of the support and apparent protection suggested by the dimly lighted hole in the frame, while quiet reigned and when man was absent from the scene, and then held to by instinct and association, in spite of drawbacks however formidable. Attachment to the chosen site is instinctive and increases hourly, while it is also strengthened through association, which may come in time to rob every kind of noise and disturbance of its terrors. While the ascending curve of attachment, heightened by the guarding instinct, rises rapidly, the curve of fear is correspondingly depressed. The question is first a specific, and then an individual problem. The upward curve ascends more rapidly, it may be, in bluebird than in cedar waxwing, but again this ascent may be steeper in one bluebird than in another, more abrupt in a town robin than in one born and bred in the woods. The last court of appeal in such a case will always be the experience of the individual, and the mutual reactions of the pair.

On the contrary I would not affirm that the robin's nest which I have seen built on the stringers of a railroad bridge, but a short distance below the level of the rails was built during a long interval of quiet. The interval required may in certain cases indeed be very short, and its necessary length will depend again upon the history and instincts of the mated pair. Of all such experiments which are tried by birds we may be sure that many fail.

*Individual change in nest site.* While many individual eagles, hawks, robins or sparrows which habitually nest aloft or at a certain height from the ground, occasionally come to the earth, while others like the herring gulls and mallard ducks which as commonly build upon the ground will sporadically ascend and place their nests in trees and often at a considerable height. To attribute such actions to the lessons of experience, as has often been done, is quite as justifiable in one case as in the other. Such conclusions seem to be rather gratuitous, and lacking in the proper kind of supporting evidence. We do not rule experience out of the problem of behavior at this point, but are convinced that most of such minor individual changes are due to other causes.



Audubon's<sup>24</sup> remarks on the herring gulls on White Head Island at the entrance to the Bay of Fundy, have often been noticed. At the time of his visit, on May 22, 1833, he was surprised to see their "nests placed on branches, some near the top, others about the middle or on the lower parts of the trees, while at the same time there were many on the ground." To Audubon the owner of the island declared that the habit of nesting in trees had been acquired within his own recollection, for he said, "when I first came here, many years ago, they all built their nests on the moss and in open ground; but as my sons and the fishermen collected most of their eggs for winter use, and sadly annoyed the poor things, the old ones gradually began to put their nests on the trees in the thickest part of the woods. The younger birds, however, still have some on the ground, and the whole are becoming less wild since I have forbidden strangers to rob their nests."

The conclusion thus drawn in regard to the cause of the change in habits observed, is not strengthened by the further statement of Audubon that "on some of the islands not far distant, to which the fishermen and eggers have free access, these gulls breed altogether on the trees, even when their eggs and young are regularly removed every year," and that "the young on the trees are shaken out of their nests, or knocked down with poles, their flesh being considered very good by the fishermen and eggers, who collect and salt them for winter provision." Some of these birds nested as high as forty feet or more, and Audubon predicted that after further molestation they would go still higher, and finally build in security in the rocky shelters on the summits of some of the islands, as a few had been reported to have done already.

If the variation in nesting habit noticed above were the result of intelligence, we should expect that the birds would take a further step and abandon their island altogether when the limits of persecution had been reached. But this logical step seems to be never or but seldom taken, as shown by the history of the Hebrides and other rocky islands to the north of Scotland and Ireland, of Ailsa Craig, or of Bird Rock. Indeed there are few rock pinnacles or ledges which the intrepid eggers cannot reach, and in some places as at St. Kilda, they have plied their trade

<sup>24</sup> Op. cit., vol. iii, p. 588. Edinburgh, 1835.

for ages, with the aid of ingenious snares, poles and ropes. Yet true to the instincts and traditions of their race the many kinds of sea fowl, though regularly robbed, resort each year to their rugged homes to breed. We are reminded of the compass like precision with which many birds keep to the fatal overland and coast routes in Italy and other parts of the Mediterranean, which they have followed for ages, in spite of the terrible persecution which has awaited them each year, not to speak of other migration routes over sea, which at the time of their origin, for all we know to the contrary, were really over land. Fortunately some of these wonderful bird colonies, which now represent but the remnant of the hosts of an earlier day, are being wisely preserved.

My own experience with the herring gulls has been gathered from studies of the two largest communities on the New England coast, at the Duck Islands, Maine, which lie from five to seven miles to the south and east of Mount Desert. Both islands are partially wooded, but the lesser to the north is occupied only by semi-feral sheep and still wilder sea fowl; it supports the larger community of gulls, the nests of which are scattered over the rough bush grown slope of its southern side. The birds of this community have never been strictly protected, and though shy and difficult of approach, they have never been taken extensively to breeding in trees so far as known.

On Great Duck there is a fine colony of upwards of 4,000 birds which occupy a more restricted area of high rocky shore and fallen spruce woods, now largely clear, especially in the vicinity of the Government Lighthouse, at its extreme southern end. Though shamefully persecuted from the days of the Indian on both of the islands, the colony of Great Duck was taken more especially under the protective shield of the Audubon Society about twelve years ago. Its nests are more concentrated, and its members less shy than on the smaller domain, but so far as I have been able to learn the habits of both communities have remained essentially the same from an early day. At either point comparatively few birds have taken to building tree nests. To have formerly disturbed them by firing a gun, or by a succession of dynamite blasts as I had occasion more recently to observe, was to throw a large part of the com-

munity into panic, when they would ascend to a great height, or leave the island until peace was restored.

In any event, building their nests in trees, as a few now do at a common height of from six to ten feet, could have afforded them no protection from man, and probably none from their one other inveterate enemy, without their own ranks, the crow, which still harries their nurseries at will.

A census of 100 nests of this gull, taken at random, was made on the island July 17, 1902, and in regard to position gave the following results:

Ground nests, often placed under dead spruce.....	89
Tree nests in upright spruce, either living or dead, 1 to 9 feet.....	6
Rock nests, on ledges, and usually nearer the sea.....	2
Nests on logs or fallen trees.....	3
	<hr/> 100

Had this survey been made on the confines of the colony the number of nests placed on bare rocks would have been greater, but so far as trees are concerned the results would have been essentially the same.

In relation to tree nesting another question must be considered, and that is the restrictions imposed upon the young, especially when their nests are at a considerable height. As I have shown in an earlier paper <sup>25</sup> the gull community is organized on a peculiar basis, and this is particularly important in such crowded communities as found at Great Duck. Each pair of birds discriminates their own chicks with precision, and guards the territory or preserve on which are placed their nest, cover for the young, perches and feeding spots, with the utmost vigilance. Trespassing adults are fought off, and straying chicks are quickly struck down and often killed in cold blood, unless protected by their parents. The admirable guarding instinct is thus the cause of many untimely deaths in every community, and numbers of recently slain birds of all sizes can be seen any day upon the breeding grounds. Now nesting in trees would undoubtedly tend to check the errors of instinct in permitting the too early or too indiscriminate straying of the young, and thus be a source of protection. Without any doubt young are liable to fall out of the nests when close to the ground, but at

<sup>25</sup> Organization of the Gull Community. Proceedings of the Seventh International Zoological Congress. Cambridge, 1909.



a height of from 10 to 40 feet they would be likely to remain until ready for flight, as Audubon remarked. The tree nests, as this excellent field naturalist also noticed, are considerably greater in circumference than those built on the ground, and this fact tends to greater security from accidents, while it affords the chicks more ample room for exercise. On the whole tree nests undoubtedly favor the gull chick, but they do not favor the parent directly for it must bring more food to satisfy the hunger of its young; evidently there can be no foraging for insects, a privilege enjoyed by all birds reared upon the ground, for many weeks, before they take to the water and are ready for flight.

Upon the strength of all the facts at hand we are bound to conclude that individual variation in the position of the nest for the gull, has no immediate reference to protection from man or from its few common enemies; it may favor the young under certain conditions, but the variation is often of too slight a character to have any significance. This was particularly well illustrated in an allied species at one of the little Weepeeket Islands, in Buzzard's Bay, Massachusetts, where in July, 1902 I found a single nest of the roseate tern, raised two or three feet above the level of the rocks and sand and fixed between upright culms of sedge, a variation in building habit the more striking since all the other nests were upon the ground. Here again the variation could not be attributed to protection either sought or gained, since it was the most conspicuous nest of the little colony.

Many cases could be given of novel, difficult or even fatal nest sites being adopted by various birds, and in the first instance repeatedly chosen, regardless of the teachings of experience. A good illustration of the latter is seen in the stupid persistence of the eaves swallow or house martin (*Hirundo urbica*), as described by Gilbert White.<sup>26</sup> "Birds in general" says the naturalist of Selborne, "are wise in their choice of situation; but in this neighborhood every summer is seen strong proof to the contrary at a house without eaves in an exposed district, where some martins build year by year in the corners of the windows. But as the corners of these windows (which face to the south-east and south-west) are too shallow, the nests are

<sup>26</sup> Natural History and Antiquities of Selborne. London, 1883, p. 137.

washed down every hard rain; and yet these birds drudge on to no purpose from summer to summer, without changing their aspect or house. It is a piteous sight to see them labouring when half their nest is washed away, and bringing dirt 'to patch the ruins of a fallen race.' "

The American robin, to cite another instance, has been found nesting in the drooping slender branches of the weeping willow, and in an osage orange bush,<sup>27</sup> where the mother was found impaled on one of its thorns. Such instances are wholly exceptional, but it cannot be confidently asserted that they are always the result of youth or inexperience.

It appears to be equally futile to attribute the act of occasionally nesting on the ground on the part of any species which habitually goes higher to the needs of protection as the result of experience; all such nests are very unsafe, and birds like the song sparrow which frequently indulge in the practise, are apt to lose their broods when the sitter is not wiped out in the bargain. About the only way I can be sure to preserve such nests when found, is to fence the whole with a fine wire screen. To conclude, the golden eagle which is limited to no narrow range, and can take care of itself under most circumstances, commonly selects a lofty tree where its huge nest stands out like a castle on a hill, or a rocky hill top or precipitous cliff in the mountains or by the sea, but on occasion, when possibly induced by the greater accessibility of food, it has been known to rear its home in far humbler surroundings, on the treeless plain.

*Size of the nest.* The size and weight of individual nests are subject to greatest variation in those of the statant type, a fact dependent mainly upon the nature of the site and immediate support. Thus when other conditions are approximately uniform we should expect to find robins' nests, built upon flat shelves and protected from the weather, to vary far less in these respects than when placed in crotches or upon inclined branches of trees. The bluebird and house wren which commonly adapt natural and often contracted cavities to their needs, usually carry in little building material, and this is molded to form a scant lining, but when coming to a box or bird house they will fill the whole space before modelling an inner nest wall at the farther end for immediate use. Under such conditions the

<sup>27</sup> Dawson and Jones. The Birds of Ohio. Columbus, 1903, vol. i, p. 224.

amount of material may be ten times greater than is commonly used, and such proceedings undoubtedly render them safer from the annoyances of other birds. It appears like a measure to secure protection; at any rate it is an adaptation to surrounding conditions.

Whenever a bird of this group (see table II, of part II, No. 3, i. b.) makes a nest of odd or irregular form, it would be well to carefully examine the site, to which it may be merely a clumsy adaptation, and to note in particular the size and character of its inner wall, before hastily inferring that the bird was blundering in the dark, through inexperience, or the loss of its "copy book," so to speak. The variation may prove to be unimportant, the inner wall (character No. 1 of the analysis given above) conforming strictly to the specific type.

The size and "perfection" of the nest is subject to a number of variables (see p. 177 of part I), some of which are hard to determine. When the first egg is laid before the nest is completed, the building instinct is liable to subside, and a somewhat scamped or imperfect nest to result. Echoes of this instinct, however, are sometimes perceived many days after the eggs have appeared and incubation is well advanced. Thus the great herring gulls are likely to add fresh materials to their nests at any time, and I have seen this bird while brooding her eggs, reach down with her bill, pull a little fresh grass by the roots and drop it on the nest wall or tuck it underneath her body; the white-bellied martin will return feathers which have blown from its box, even after its young are fledged, and both eagles and hawks occasionally bring a fresh spray of evergreen or seaweed to their eyries, but we should not be justified in referring such acts to the building impulse, without a knowledge of all the factors which mold conduct at other times and under other conditions. Thus the gulls are constantly pulling and carrying about what looks like nesting material, whether they are building a nest or not, and whatever the condition of their eggs or young.

A case has indeed been recorded in which the walls of a hummingbird's nest were gradually raised from the time the eggs were laid until the young were fledged, when the structure had grown to more than twice its original size. The behavior of the gull just noticed should throw some light on such acts, and



the inference that measures of this sort are adopted to save the young from falling out of the nest receives no support.

*Compound or superimposed nests.* We have been considering simple, individual nests, but have earlier referred to aggregated nests, or those composed of closely associated units, such as are made by the sociable grosbeaks (see p. 184 of part I), or the waxwing (*Dulus dominicus*) of San Domingo, as well as to compound nests representing a more or less extended series of "supra" or "inframposed" structures, as in certain gulls, eagles, doves, warblers, vireos and weaver birds, whenever an old nest, whether of the same or of different individuals or species is used more or less completely as the site of a new one. Under such conditions the greatest variation in size and weight may be expected.

In illustration of the foregoing remarks, compare the first season's nest of a robin, with the same when used for a second brood, the nest of a herring gull "repaired," and occupied the following year, as was reported by Audubon<sup>28</sup> and has been noticed by others since, the eyries of the eagle and fish hawk, which are occupied for successive years, and which vary in height in proportion to their age, within the limits of stable equilibrium. This increase is to be observed in the white headed eagle under certain conditions, but would not hold where the nest was diminished through the process of natural decay. The greatest recorded period during which a given nest and nest site has been continuously occupied, is considerably over the century mark. Thus, according to Newton, an eyrie of the falcon (*Falco peregrinus*) on Arasaxa, a hill in Finland, was in continuous use for 119 years (1735-1855), and an earthenware bottle or its substitutes, in the branches of a tree in a garden at Oxbridge, England, was known to have been used by the blue tit (*Parus cærulens*) from 1779 to 1888. We have finally to notice the remarkable "storied," or serially superimposed nests which a yellow warbler or vireo will sometimes build, whenever their breeding cycle has been repeatedly broken by fear, and the site of the old nest is successively chosen as that of a new one.<sup>29</sup> In this way, as we have shown, the parasite's eggs are admirably "concealed," and its designs frustrated.

<sup>28</sup> Op. cit., vol. iii, p. 590.

<sup>29</sup> For illustrations and fuller discussion see *Instinct and Intelligence in Birds. Popular Science Monthly*. New York, 1910, vol. lxxvii, p. 87-92.

The remarkable pendent nest of the Indian weaver bird (*Ploceus baya*) consists of a grass lined globular chamber which is suspended to a branch by a long fibrous cord and extended below in a regular, woven tube which serves as entrance. Such a nest may be used for successive years when it becomes compound by the addition of new chambers below the last in succession, until in one case recorded there were seven "stories," the last of which, being made of fresh grass, probably represented the nest of the current year; yet three of the lowest chambers, if not in actual use, at least contained eggs. Such "infra-imposed" structures are clearly comparable to the compound nests of the fishhawk and eagle or even of the yellow warbler already considered.

"Double" or "triple" nests placed side by side, and more or less completely joined, are rarely reported (for a beautiful illustration of a double nest of the red-eyed vireo, containing one and two eggs respectively and both male and female sitting when discovered, see Dawson and Jones "Birds of Ohio," vol. 1, p. 296); they may be due to one of several causes, but when containing eggs probably result from a disturbance of a first cycle usually after a single egg has been laid, and the building of a new nest beside, rather than *on*, the first. Such rare chances for observation should not be lost by disturbing the nests, and I think it will be found that the female completely abandons the first, and that the ardor of the male in reference to it soon dies down.

*The materials of nests and their method of arrangement.* The kinds of material used by birds in the construction of their homes has been detailed at great length; indeed it is under this head (No. 4 of analysis given above), as well as on the method of arrangement and dimensions of the walls that the literature of nests is most complete. The inferences which have been drawn from their use of materials are not so satisfactory.

The question of the kinds of material used by birds in nest building is not very important when we consider the majority of makers of increment nests. Yet there is a considerable number of species which are wonderfully uniform in both their choice and treatment of building materials. Between the extremes every intermediate degree is to be noted. On the one hand

they take from their immediate environment whatever they can use in adaptation to their needs and methods of work, while on the other they will go long distances in search of what they need or prefer, such as soft mud, spiders' silk, hair, fine vegetable substances, or even the cast skins of snakes, yet many in this case are often quick to adapt materials nearer at hand to their immediate use. The endless variations to be noticed in such particulars, while the source of much popular interest, are usually not important, because of their inconstancy. While the external form and appearance of the nest may vary considerably under such circumstances, it is safe to say that the building materials, however bizarre or incorrigible, receive the same kind of treatment, and that the inner wall is not essentially changed. Accordingly any marked variations in nests of this sort are due to accident, so far as their builders are concerned, or to the environment, rather than to any important change of instinct or habit.

The rule of coarser materials first and finer or more pliable last is seldom departed from, especially in all such as build an increment nest, of the upright standing form, and neatly mold an inner wall, though in some cases, to be sure, the nest is very uniform throughout, whether exceedingly soft as in the ruby-throat (fig. 18), the goldfinch and yellow warbler, or when made entirely of the culms of grasses or of coarser twigs. Yet I have even found the soft nestling down feathers of some wild bird to enter more completely into the lining of the hummer's nest than in any part of its outer walls.

If we were to confine our attention to certain species of birds such as the osprey (*Pandion haliaetus carolinensis*), and hooded crow (*Corvus cornix*) we should have to admit that no junk dealer could present a more motley array of articles drawn from every kingdom of nature as well as from the arts and devices of man than the nests of these birds on occasion afford.<sup>30</sup> An old broom and rake, a rag doll and toy sail boat, an old door mat, shoe brush and feather duster, egg-strings of the common conch, and coils of rope twenty feet long, tin cans as well as sea shells, bright stones, and the bleached bones of cattle, not to speak of a new hat blown from the head of an unfor-

<sup>30</sup> The following notes are drawn from "Breeding Habits of the Fish Hawk on Plum Island, New York," by Charles Glover Allen. See *The Auk*. New York, 1892, vol. ix, p. 313-321.



fortunate passenger on one of the Fall River boats, and seen in the talons of the hawk when under way to its nest, all come as perfectly to the hand of this beach comber, as the store of soda bottle wires picked up in a back yard, or the entire stock of steel spectacle frames, stolen from an optician's window in Calcutta or Bombay, suits the tastes of the unconventional crow, or indeed as the five or six green leaves or as many pebbles, at times satisfies the simpler tastes of the arctic tern at Matinicus Rock, Maine.

Again were we to examine a series of nests of either the ruby throated humming bird, the red-eyed vireo, the Baltimore oriole, or even of the robin we should have to admit that the range of choice in the selection of materials had been narrowed greatly with correspondingly greater uniformity in their treatment. Indeed we approach more nearly the wonderful uniformity displayed by the mud and paper nests of wasps, and the prismatic wax cells of the honey bee, an unmistakable index of the more complete sway of instinct in guiding the actions of the builders. We might add that the crow and his tribe, which are generally regarded as the most intelligent of birds, can seldom be trusted in the presence of any bright or shining objects whatsoever which they will carry off and either hide or work into their nests.

The nest of the common robin forms as good a text as any from which to view this subject, and we shall later see how it is built. Probably in not one nest in a thousand, examined by interested persons, have the conditions under which it was built been accurately known; yet it is these conditions, such as the state of the weather, the nature of the site, and the character of the general environment, not to speak of the synchronization of the instincts, which mainly determine the character of such nests; the more uniform the conditions the more stereotyped the result. Upon a foundation of dead weeds and stubble this bird usually raises a clay cup; the softened mud and other materials are well incorporated to form a consistent mortar, and a lining of finer grass is usually added. Now either a lack of suitable materials, as in times of drought, or of the proper instinct causes some robins to dispense with the mud cup, while prolonged rains hamper all which build in exposed situations, and melt down their walls as fast as they can raise them. Where

mud is essentially lacking in a finished nest, a deep foundation and thick wall of dead grass and stubble is commonly found. All that we can say at present is that while mud is regularly used in a peculiar way and with a definite result, it is sometimes wanting, the only earth present being that which incidentally clings to the roots of stubble pulled from the ground.

I have a robin's nest taken from the spruce woods on Great Duck Island, Maine, which is composed wholly of coarse spruce twigs, black peat, and a lining of withered grass blades, materials which were available in the immediate vicinity of the nest. It is the only specimen which I have seen built so largely of coarse stiff twigs, but the dimensions of the inner wall, and the treatment which the material received are typical. The variation was evidently a response to the immediate environment, and is unimportant. Nuttall speaks of a nest of this bird, "bottomed" with a mass of pine shavings taken from a carpenter's bench, a variation similar to that mentioned above. Again if given strings or streamers of colored yarn, though white is preferred, robins often take them eagerly and work them more or less effectively into their nests. I have even seen a pocket handkerchief which a robin picked from a line or from the ground and carried into a tree, where, however, it was caught so that the bird failed to use it.

The fact that the robin brings plastic earth to its nest in two ways, incidentally in the damp soil clinging to the roots of pulled grass or stubble, and directly in large lumps of barely consistent mud, and that all is treated in a fairly definite manner to mold a symmetrical cup is a highly interesting fact, for it suggests the origin of the direct use of mud in all such building operations. A more durable and better nest resulting from the casual use of plastic earth thus accidentally introduced at an early stage of the proceedings may have furnished, on the principle of selection and other possible factors of evolution, the starting point for what in the course of ages became a fixed and settled custom.<sup>31</sup> The fact also that its near ally, the black-bird of Europe (*Merula atra*), builds in precisely the same style, not only suggests the high antiquity of the practise, but illus-

<sup>31</sup> It should be added that in exposed situations and when subject to drenching rains the mud cup is distinctly disadvantageous, since without drainage below, the nest is liable to catch and hold too much water.

trates the fixity of such an instinct when definitely established and correlated with other actions. The robin does not inherit the instinct to use mud in nest-building, any more than it inherits the tendency to use weeds, sticks or grass, or the hummingbird, lichens, but it is born endowed with tools and with tendencies to use them in a more or less definite manner upon plastic and other materials drawn from its environment, although in this bird certain kinds of material more readily awaken its building responses than others.

In describing a series of nests of the English merle or black-bird Rennie<sup>32</sup> remarks that the outer framework differs but little from that of the song thrush (*Turdus musicus*), or mavis, "except in being more massive, as is also the clay lining, which is put on in a very wet state, probably to save the saliva of the bird; but to prevent this moisture from injuring the eggs, it is lined with a thick bedding of dry hay, which in some nests is very neatly worked into the hollow formed by the clay, while in others it is laid less skillfully, and hence the nest is rendered very shallow. In two of the nests in my possession the masonry of the clay is carried around the branch of the bush where they were built, in order to make it fast, which circumstance, as it is not of usual occurrence, shows that the little architect was guided by intelligence akin to rationality, if not identical with it, and not by what is usually called blind instinct." We give this description for the sake of comparisons with the American robin; in our bird the lining is sometimes of *green*, not dead or dry grass, and is sometimes dispensed with altogether; the lining in all probability has nothing to do with moisture, and though it forms a softer bed for the eggs it is often so slight in the robin as to suggest that it may be only the relic of a period when such nests were built without the aid of the mud cup at all.

The clay cup of the robin also suggests an interesting variation in a nest of the olive-backed or Swainson's thrush in my possession,<sup>33</sup> and at the same time illustrates the importance of the study of behavior, as a check to the interpretations of structure. Of the two nests of this species, which I have to describe, one was from a pasture, the other from a peat swamp. Let

<sup>32</sup> Op. cit., p. 131.

<sup>33</sup> I am indebted to Miss Cordelia J. Stanwood of Ellsworth, Maine, for this as well as for many other rare or interesting nests which she has collected in the course of her studies of the bird-life of that region.



us see how the immediate environment has apparently affected the work of the builders in each case. The first is typical of this bird, and was built in a fir tree at a height of five feet from the ground. It is rather bulky, though smaller than a robin's, standing  $3\frac{1}{2}$  inches, when removed from its support. The cup is well modelled, and measures 2 inches deep by  $2\frac{1}{2}$  inches across at the brim. Though the walls reach a thickness of two inches, being rather loosely compacted of vegetable matter only, the whole is very light, weighing barely an ounce. Fine fir twigs, rather fine dry grasses and rootlets, interspersed with *Polypodium* and other mosses constitute most of the building materials, the cup being lined with the skeletonized leaves of a wild cherry and a jet black vegetable fiber suggesting horse hair, and probably representing setae of one of the mosses.

The other nest, though thinner in construction weighs more, and appears to have an earthen cup, fairly well modelled and compacted, like a robin's. It was found in a peaty meadow, and was taken when the young left it on July 12, so that its lining has been more or less pulverized through use. The suggestion that this bird has adopted the robin's peculiar methods, however, is quickly dissipated, when we examine it more closely, remember the environment, and the probable habit of using moss in this species as the robin pulls stubble, and the amount of damp earth liable under certain conditions to be taken to the nest in consequence. The cup of this thrush's nest is not strictly a "mud cup" at all, but appears to be formed of the stalks and rhizoids of mosses pulled by the bird from the peaty swamp, and of the black earth and sand thus casually obtained; this was later subjected to the molding movements of the bird in the usual manner, and was further compacted by the weather and the activities of the nestlings. Though such a nest presents a very unusual appearance, if this interpretation is correct, it is normal in every respect.

Miss Stanwood, who has examined over thirty nests of the Swainson or olive backed thrush, writes that they all have the bulk and general appearance of the robin's, and are conspicuously placed in bushes or low trees. As many as thirty kinds of vegetable materials sometimes enter into their loose outer wall, while a thick inner layer of dead wood, which seems to correspond to the mud cup of the robin is usually present and

is held in place by masses of fine rootlets; the lining proper, which always shows some skeletonized leaves, is of usnea lichen, green moss or fine black vegetable fibres of some sort.

In marked contrast to most builders of increment nests already referred to, which appropriate all kinds of objects regardless of their form, color, or origin, and mold them in some fashion to their use, stands the stereotyped performance of many mud



FIGURE 11—Nest of the American redstart (*Setophaga ruticilla*) illustrating perfect modelling and symmetry of cup, in simple adaptation to support. Diameter of cup, 43 mm. ( $1\frac{1}{8}$  inches): depth cup, 35 mm. ( $1\frac{3}{8}$  inches): diameter nest at rim, 60 mm. ( $2\frac{3}{8}$  inches): total height, 80 mm. ( $3\frac{1}{8}$  inches): materials chiefly fine bark strips, coarser without, and secured with spiders' silk: cup molded out of the blades and stems of very fine grass: in gray birch, 12 feet up. Ellsworth, Maine.

plasterers like the eaves swallows and oven bird of South America, or of saliva workers, such as the swifts. The nests of the esculent swiftlet (see fig. 7, part I) are compacted of hardened saliva only, and are highly uniform in size and shape, while the

common chimney swift in building (see fig. 8) uses only slender dead and brittle twigs, which are snapped off on the wing; they are further glued to their support and to one another by means of viscous saliva, and with the uniformity of a basket weaver's art. (For example of nest showing greater variation in materials, but perfect in type see fig. 11.)

*Appropriation of nest materials illustrated.* While certain birds, as we have seen, go far at times to find suitable nest materials, and make use of definite kinds, the majority take from their immediate environment only, and adapt whatever it has to offer to their needs. The robin in nesting time may be seen flying high with ball of mud in bill, having travelled a quarter of a mile or more for the requisite substance, but it does not follow that under like conditions all would do the same; their conduct, as we have shown, will depend upon a number of variable factors, but the rule in this instance is to take what comes nearest to hand.

The great herring gulls of the Duck Islands probably travel at least thirty miles in search of food, but in building their nests they draw only upon the resources of their island, and mainly from an area of very short radius; again I have known certain arctic terns on Matinicus Rock to gather everything used in building their nest within the compass of a square yard, or even to limit themselves to the leaves and pebbles within reach of bill, while sitting on the chosen site. The ospreys on Plum Island, on the other hand, were formerly known upon occasion to levy tribute from a distant shore.

The appropriation of nesting materials from the nearest source was well illustrated by red eyed vireos and cedar waxwings in central New Hampshire. Now it is the practise of these vireos to line their nests either with fine bark strippings or with old needles of the white pine where both abound, but in other parts with bast alone. The question arises whether the species is split up into certain gens, one favoring this and another that material, or is it a case of individual preference, dependent upon the environment mainly; we cannot answer definitely, but are inclined to the latter view. A nest of this vireo referred to (No. 2, table 3), was built in a maple tree, close to a dwelling house; the frame of this nest was made entirely of grape vine bark, the finest strippings being worked into the inner wall.



One rod distant from the tree stood a number of white pines, and their withered needles littered the ground all about, while at thrice this distance in another direction a grape climbed into an apple tree. It is possible that discovery of the vine in the first instance immediately awakened in this individual the building responses, and decided in favor of the bast; at least the case of the cedar waxwing, which is typical of many others,

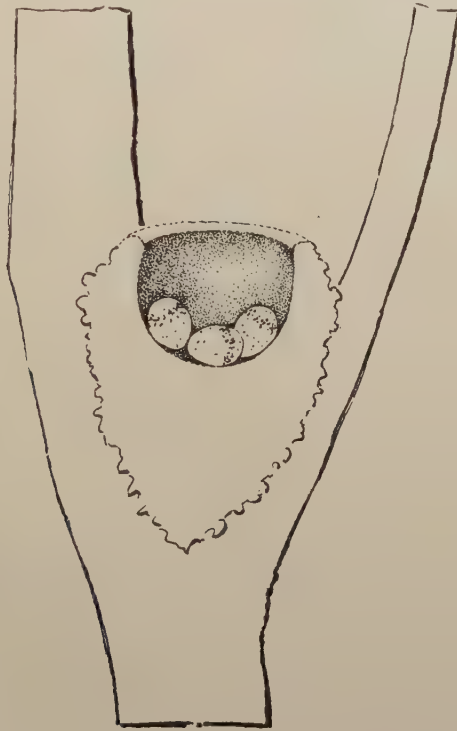


FIGURE 12—Sectional view of nest shown in figure 11 and drawn to the same scale, to show form and symmetry of cup, and relation of entire nest to support.

points to this conclusion. In nests of the vireo from northern Ohio, where the white pine is but rarely if ever found growing under natural conditions (compare nest No. 3, table III) the bast habit seems to prevail.

In line with the maple referred to above stands a larch, in which a cedar bird built a neat nest; this was wholly framed of the dead brittle twigs of the tree and lined with pine needles, all having been evidently gathered from the ground below.

Further, in an orchard on the opposite side of the house, but less than five rods from this point, another waxwing built a grass nest and used as lining the fluffy heads of the low cudweed, patches of which were growing on the hillside close at hand. Without splitting words on the subject of "choice" in such selections, it is evident that a great variety of natural products awaken certain responses concerned with the complex acts exhibited in building the nest, and awaken them promptly in all such birds.

We have already spoken of the general methods of arranging the materials used in building (No. 3 of the analysis given above), and are now ready to consider the most constant characters of nests (Nos. 1 and 2), the form and dimensions of the inner wall, and the treatment of the outer surface when characteristic. To repeat, we find the characters of the inner cup, and of the outer surface when subjected to peculiar methods of molding, smoothing, or incrustation, the most constant characters of increment nests, because due to instinctive activities of uniform type. The amount and nature of the substances employed are as a rule quite subordinate to the methods of work. When the outer wall does not undergo a peculiar smoothing or garnishing process the nature of this surface is subject to greater variation and is consequently unimportant.

##### 5. VARIATIONS IN THE NESTS OF CERTAIN BIRDS

The uniformity and variations in the characters of nests already enumerated and described will be further illustrated by specimens of the work of red eyed vireos (*Vireo olivaceus*), wood pewees (*Contopus virens*), and the hummingbirds. These particular nests may be regarded as typical examples, but to give numerical results of any worth large numbers of specimens, drawn from every part of the known range of the several species would have to be examined.

*Variation in nests of the red eyed vireo.* We have seen that nests of the pendent type are much less variable in regard to the characters given above than in most of those built upon a basal support, and they are seldom found close to the ground. The supports chosen for such hanging nests are of necessity more uniform, and the nests themselves present a corresponding similarity in their measurements, as well as in the kinds and

quantity of material used. This is well illustrated in nests of the red eyed vireo from Maine, New Hampshire and Ohio, as detailed in table III.

TABLE III  
VARIATION IN NESTS OF THE RED EYED VIREO

No.....	1	2	3
Place.....	Ellsworth, Me.	Northfield, N. H.	Cleveland Heights Village, O.
Diameter of cup.....	2.3 inches	2.2 inches	2.2 inches
Depth of cup.....	1.5 "	1.5 "	1.5 "
Outer diameter.....	3.6 "	3.1 "	3.1 "
Outer depth.....	2.5 "	2.2 "	2.3 "
Thickness of wall at base.	0.7 "	0.6 "	0.5 "
Angle made by twig supports.....	85° and 45°	60°	85°
Materials.....	Pliable bark strip-pings, white cocoon silk of spiders, and paper.	Grape-vine and birch bark, cloth, wasp-nest paper, spider cocoon silk and elm seeds.	Mainly bark strips of the grape and yellow birch, rootlets, thread, and spiders' silk.
Lining of cup.....	Pine needles.	Grape-vine bark stripped very fine	Fine bark strips and rootlets.
Means of suspension.....	Mainly egg-cocoon silk, with bark and paper.	Mainly cocoon silk, bark strips and cloth.	Spiders' silk, thread and bast.
Situation.....	Witch hazel.	Red maple.	Red maple.
Height from ground.....	5 feet	15 feet	20 feet

The building of nest No. 3 was watched from a good vantage point and will be later described. This was the poorest in point of construction, and not having been preserved until after some time, it is somewhat damaged. The others are perfect, and brand new in appearance. Attention is particularly called to the practical identity in the measurements of their inner walls, as well as in their other essential characters. While a greater series would unquestionably show more marked differences, we should not expect the variations to be very great. The chief apparent differences, though of no real importance, appear when these nests are viewed from their under sides, No. 3 being weathered to a dark gray, while No. 1 (see fig. 9, part I), which is frescoed all over with paper and floss silk, is nearly white in consequence. This silk, which was stolen from the egg cocoons of spiders, and when not bleached, is of a light cream color, is not only drawn out to secure every part of the



surface, but is felted over the forked twigs to form a very serviceable support; there is almost enough silk to make a spool of thread. Nest No. 2 is intermediate in this respect, being grayish brown, and flecked with spiders' silk and birch bark curls. The last of the three nests suffered from being built in too wide a crotch, without the aid of a subordinate twig as in No. 1, to reduce the angle. The strength of suspension, which seemed to satisfy the builder, was so weak that it had to be reinforced to save her eggs.

*Variations in pewee's nests.* The wood pewee, like the hummingbirds, treats the outer wall of its nest in a highly peculiar



FIGURE 13—Nest of wood pewee (New Hampshire) to illustrate uniform treatment of diverse building materials. See No. 1, table IV, and compare figure 14. Egg inserted to mark level of cup.

manner, by frescoing it with lichens, or similar vegetable substances, thus rendering it inconspicuous, and done as some think for the purpose, or by way of ornament.

Of the two nests of this pewee available, the first (fig. 13) was saddled to the horizontal branch of an apple tree of an orchard in New Hampshire, within easy reach of pine and hemlock woods; the dimensions in either case are given in table III. It is rather bulky for the bird, and is wholly composed of four kinds of material, light green usnea moss, which is often seen hanging in streamers from the dying branches of crowded pines in damp

situations, interworked with very fine twigs of hemlock, while the outer wall is incrustated with gray lichens, and flossed over with spiders' silk.

The Ohio nest (fig. 14) presents quite a different appearance, in both bulk and quality, though agreeing with the first in all



FIGURE 14—Nest and eggs of the wood pewee (Ohio). Photographed to same scale as figure 13, which see, and also No. 2, table IV.

TABLE IV  
SHOWING VARIATIONS IN NESTS OF THE WOOD PEWEE

No.....	1	2
Place.....	Northfield, N. H.	Euclid, O.
Diameter of cup.....	1.7 inches	1.7 inches
Depth of cup.....	0.7 "	0.8 "
Outer diameter.....	3.4 "	2.8 "
Outer depth.....	1.7 "	1.8 "
Thickness of wall at base.....	0.9 "	0.9 "
Greatest thickness of side walls.....	1.3 "	0.9 "
Materials.....	Usnea, hemlock twigs, lichens, and spiders' silk.	Bark strippings, rootlets, fine twigs, weeds, lichens, and spiders' silk.
Lining of cup.....	Light green usnea. Horizontal (dead?) branch of apple.	Jet black rootlets. Horizontal dead branch of beech.

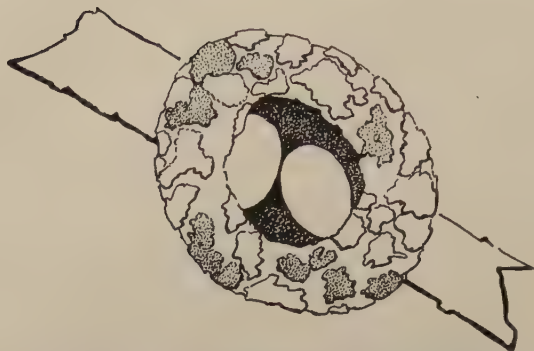


FIGURE 15—Nest and eggs of the ruby-throated hummingbird, attached to twig, seen from above, showing smoothed, felted wall, and fresco of lichens: patches represent bits of a light gray lichen, stippled when attached with dark under side up. Natural size.



FIGURE 16—Sectional view of nest of ruby-throated hummingbird shown in figure 15, illustrating symmetry of cup, the incrusting process carried to overarched rim, method of building up the lower side to compensate for incline of twig, and the wafer of saliva (*W*,) by means of which the nest is glued to its support. Natural size.

essential measurements. It is mainly composed of fine grape bark strippings, and black, rather coarse and unmanageable rootlets; the latter form the inner wall exclusively, and being too springy to mold well, make a ragged rim, over which the scanty fresco of lichens has not been carried; its shallow cup is barely deep enough to hold the cream white, spotted eggs, which



in this case stand out boldly from a black background. These nests, though dissimilar in outward appearance, agree in all essential respects, in the treatment of the outer and inner wall, and in the dimensions of the cup. The differences are unimportant, because plainly due to different environments.

*Variations in Hummingbirds' nests.* The hummingbirds' nests examined pertain to the ruby throat (*Trochilus colubris*), from the eastern states, the Anna (*Calypte anna*), the black-chinned (*T. alexandri*) and Allen's hummingbirds (*Selasphorus alleni*) from California, and the broad tailed hummer (*S. platycercus*) from the Santa Rita Mountains, Arizona.<sup>34</sup>

Hummingbirds build the smallest and most delicate nests known,<sup>35</sup> but the examination of their work brings out the same kind of facts which we have seen in dealing with other and larger species. There seems to be not only a general agreement in the nests of different species and genera, but a striking uniformity in essential characters, and this is the more pronounced when different specimens of the same species are examined.

Hummingbirds exhibit the tendency to saddle their nests on small twigs and at a point where they fork (fig. 17); at times the base of their nest is continued around the main support, thus affording greater security. The ruby throat and Allen's hummingbird first spread an adhesive plaster of saliva on the chosen twig, and building upon the wafer thus formed literally glue their nest to its support like the swift. Whether this is an invariable practise or not could not be decided from the material at my command. All build of the finest and softest vegetable substances, in which the microscope reveals plant down and pappus of various kinds, the hairy coats of seeds, bud scales and the petals of flowers. In the nests examined animal products were limited to the nestling and small contour feathers of birds, a few horse hairs, and in one instance, peculiar short quills suggesting those of a hedgehog, but probably coming from a bird. (See fig. 17.)

The materials of the nests examined, whatever their appearance or quality, are treated in a similar way, being felted and molded more or less compactly, and bound with spiders' silk.

<sup>34</sup> For the privilege of examining these nests I am indebted to Dr. W. H. Valway, and Professor Hugh D. Pallister.

<sup>35</sup> With the possible exception of the tree swifts: see p. 171, of part 1.

TABLE V  
VARIATION IN HUMMINGBIRDS' NESTS

Species.....	Ruby throat 1	Ruby throat 2	Black chinned 3	Black chinned 4	Anna 5	Broad-tailed 6	Allen's 7
No.....	Cleveland, O. 0.94 inches 0.69 " 1.43 " 1.20 " Dull brownish gray.	Cleveland, O. June 15 0.94 inches 0.812 " 1.69 " 1.31 " Light gray.	California May 1 1.00 inches 1.12 " 1.69 " 1.25 " Dull white.	California May 1 0.75 inches 1.56 " 1.00 " Clear cream color.	California 0.89 inches 0.50 " 1.50 " 0.75 " Light gray.	Arizona 0.88 inches 0.50 " 1.62 " 1.12 " Greenish gray.	California April 27 0.93 inches 0.62 " 1.93 " 1.00 " Dark gray.
Place.....	Cleveland, O.	Cleveland, O.	California	California	California	Arizona	California
Time.....	June 15	June 15	May 1	May 1	.....	.....	April 27
Diameter of cup.....	0.94 inches	0.94 inches	1.00 inches	0.75 inches	0.89 inches	0.88 inches	0.93 inches
Depth of cup.....	0.69 "	0.812 "	1.12 "	1.56 "	0.50 "	0.50 "	0.62 "
Outer diameter.....	1.43 "	1.69 "	1.69 "	1.56 "	1.50 "	1.62 "	1.93 "
Outer depth (avg.).....	1.20 "	1.31 "	1.25 "	1.00 "	0.75 "	1.12 "	1.00 "
Color of nest.....	Dull brownish gray.	Light gray.	Dull white.	Clear cream color.	Light gray.	Greenish gray.	Dark gray.
Materials.....	Fine plant down chiefly	Fine plant down, with pappus, seeds, bud scales, and two horse hairs smeared with saliva.	Fine felled plant down.	Almost wholly a fine granulated vegetable substance, probably a seed parachute, with few birds' feathers.	Fine plant down, with seeds, pappus, and seeds of composite; interlaced with spiders' silk. A few fine quills worked into wall.	Fine plant down, composed of pappus, paleae, with seed scales, bark strips, vegetable fiber, and small birds' feathers.	Gray pappus, with seeds and fine bark strips secured with spiders' silk and fine bark fibers.
Lining (inner wall)	The same.	The same.	The same.	The same.	The same.	The same, with down feathers of nestlings.	The same.
Surface (outer wall).....	Smooth, frescoed with bits of lichens, secured up or down with spiders' silk.	Smooth, with gray lichens secured with spiders' silk.	Smooth, with a few brown seed pods fastened with spiders' silk.	Smooth, with a few small leaves secured with silk.	Regular, encrust- ed with minute strap - shaped leaves, overlaid with egg-cocoon silk.	Smooth and regular, frescoed with fine green leaves secured as in all parts, with spiders' silk.	Regular, but not compact; ornamented with lichens and strips of bark, attached with spiders' floss.
Position.....	On twig.	At branching of beech twig, $\frac{3}{8}$ inch in diameter.	At branching of twig, $\frac{1}{2}$ inch in diameter.	At branching of twig, $\frac{3}{8}$ inch in diameter.	On flat crotch of branching twig, $\frac{1}{2}$ inch in diameter.	At branching of twig, $\frac{1}{2}$ inch in diameter.	On horizontal twig, $\frac{1}{2}$ inch in diameter.
Fixation.....	Nest material partly carried around stem. Saliva wafer <sup>3</sup>	By large wafer of saliva at base.	No saliva fixative.	No saliva fixative.	No saliva wafer.	No saliva wafer.	By cake of saliva at base.

<sup>1</sup> Diameter at brim, 0.75 inches.      <sup>2</sup> Probably too large; nest not quite perfect.      <sup>3</sup> Nest detached when examined.

The outer wall is smoothed and generally encrusted with fine vegetable substances, such as bits of gray lichen in the case of the ruby throat, or with minute leaves which were sometimes green when laid, with small fragments of bark, or the diminutive seed vessels of plants. A glance at the colors of such nests (table V) followed by an examination of their supports and the scanty incrustation which their walls often receive, shows the hand of instinct as plainly here as in other nest building operations. That such birds often fresco the outer walls of their nests in such a way as to protect them by making them blend with their surroundings and at the same time adorn them by making

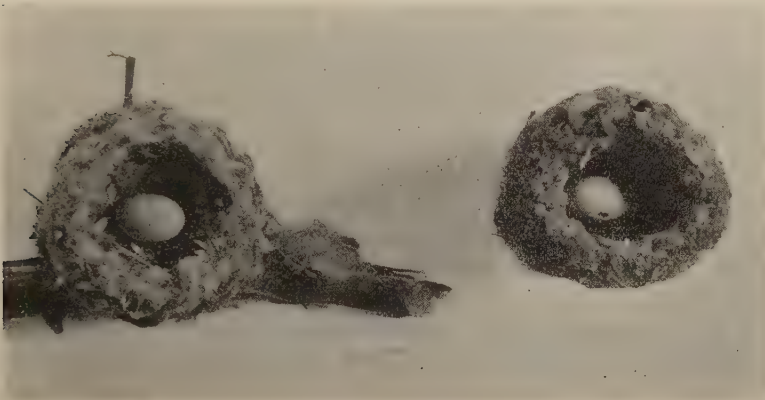


FIGURE 17—Nest and egg of the anna hummingbird, attached at branching of twig by spiders' silk. See No. 5, table V. Small quills piercing this nest below egg, and at left.

FIGURE 18—Nest and egg of the ruby-throated hummingbird, detached from twig support. See No. 1, table V, and compare figure 15: to the same scale as figure 17.

them attractive to the human eye is not to be doubted, but it is hardly necessary to say that the evidence does not support the idea that they set about this labor with either end in view. Both nests of the black chinned hummingbird referred to (Nos. 3 and 4, table V) were about as conspicuous as small objects could well be, in consequence of the material used and through lack of carrying the garnishing process to the proper stage.

The nesting materials are bound together and to their support with spiders' silk mainly, though a certain amount of saliva is



liable to adhere to some of the increments, and has been detected in one or two instances, but the chief use of the salivary glue is in the wafer sometimes placed on the twig support (*w. fig. 16*). The saliva of the hummingbird, when dried out, becomes hard, brittle, and transparent like gum Arabic; when wet with cold water it swells and is opaque, but does not perceptibly dissolve, or at least not for a long time. No impression seemed to be made on bits of this substance experimented with, after immersion for several days, but in hot water solution is both prompt and complete.

The ruby throat's nest (see especially No. 1 of table V) is often so perfectly modelled, that it appears as if pressed in a mold and stamped out of soft felt or papier maché, so true and even are its outer and inner walls and so perfect the rim of the cup (see *figs. 15, 16 and 18*), the only irregularity being seen at the base where the twig was enveloped. In this fine specimen of the hummer's work the whole outer surface is well encrusted with bits of a thin gray lichen down to the very brim, which is curiously bent inwards or overhung (*fig. 16*). The lichens are treated rather indifferently, being laid now with light gray face, now with brown underside uppermost (*fig. 15*), but they are attached uniformly throughout with spiders' silk, and so far as can be determined with nothing else.

Eighty years ago a controversy was started in England on the nest building habits of the hummingbirds, Audubon having affirmed that the ruby throat of America glued the lichens in place by means of saliva. Charles Waterton, his great and unreasonable adversary at that time, maintained that this was impossible, since the very first rain would undo the work of the salivary gland.

Audubon's account of the ruby throat's nest which was challenged by Waterton, was as follows:<sup>36</sup> "the external parts being formed of a light gray lichen found on the branches of trees, or on decayed fence-rails, and so neatly arranged round the whole nest, as well as to some distance from the spot where it is attached, as to seem part of the branch or stem itself.

<sup>36</sup> *Op. cit.*, vol. 1, p. 25. For Waterton's attack, see "Mr. Audubon and his work, the Biography of Birds." *Loudon's Magazine of Natural History*. London, 1834, vol. vii, p. 67-74, followed by four distinct articles, the third on the Hummingbird (p. 67-74).

These little pieces of lichen are glued together with the saliva of the bird."

It now seems that both sides to this controversy were partly right and partly wrong. When we remove some of the incrustation from the outer wall of the ruby throat's nest and examine it mounted in cold water under the microscope, the fibrous matter is seen to consist of two kinds, namely vegetable fibers, such as plant hairs, and strips of bast, and others of animal origin; the latter, though extremely attenuated, prove to be spiders' silk, for no change is produced by boiling the water; the lichens, moreover, are lightly secured, and show no trace of saliva before or after removal. We must therefore infer that the only effective use which this hummingbird makes of its saliva in such operations is in the wafer with which its nest is sometimes if not regularly glued to its twig support. What is true of this species seems to hold for others, although the wafer was found only in the anna and the ruby throat. The egg cocoon or even the web of a spider is quite as serviceable to them as to a wood pewee or a vireo. If it is true, as Audubon asserts, that lichens are attached over the branch at some distance from the nest, the fact is very interesting, but this did not occur in any of the nests examined.

That certain hummingbirds which build hanging and swaying nests, sometimes compensate them by the addition of weights in the form of stones or lumps of earth, has been more than once reported, and a specimen of this kind may be seen in the British Museum. We regard such singular acts as strictly analogous to building the base of a nest around its support, or in favoring one side when the branch is inclined (see fig. 16), and thus bringing the cup of the nest into an upright position whatever the angle, or indeed in sticking the nest to its twig by means of an adhesive wafer. The structure and position of these birds in relation to their general habits warn us of the folly of reading a high degree of forethought and intelligence into any such acts, however remarkable.





## DESCRIPTION OF APPARATUS AND GENERAL METHOD

Labyrinth A (fig. 1) is identical in plan with a labyrinth designated as L by Rouse in his study of the pigeon.<sup>2</sup> It is 2 ft. x 2½ ft. x 7 in., inside measurements. The alleys are 6 in. wide. The partitions of this maze are of wood, while those in the labyrinth used by Rouse were of wire.

Labyrinth A, as well as the other boxes used in the present experiments, is covered with wire.

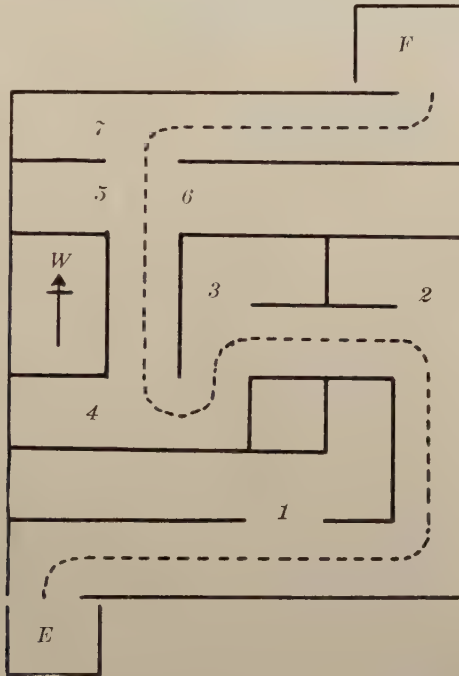


FIGURE 2—Labyrinth B. E, the entrance box; F, the food box; W, west: 1-7 indicate the blind alleys.

Labyrinth B, (fig. 2), differs from A in the number and complexity of its pathways. The results indicate that it approached very near the maximum of complexity for the pigeon. Using *l* to mean a turn to the left, *r* one to the right, and *s* a straight-ahead, the arrangement of the blind alleys from entrance to food-box may be indicated as follows: *l, s, r, s, l, r.*

<sup>2</sup> Rouse, J. E. Mental Life of the Domestic Pigeon. *Harvard Psychological Studies*, 1906, vol. 2, p. 587.

Labyrinth C, (fig. 3), was constructed in order to test kinaesthetic control in squirrels.<sup>3</sup> Hence the dimensions differ from those of labyrinths A and B. Although the alleys are narrower—5 in. wide—and not so high as those of the other mazes,

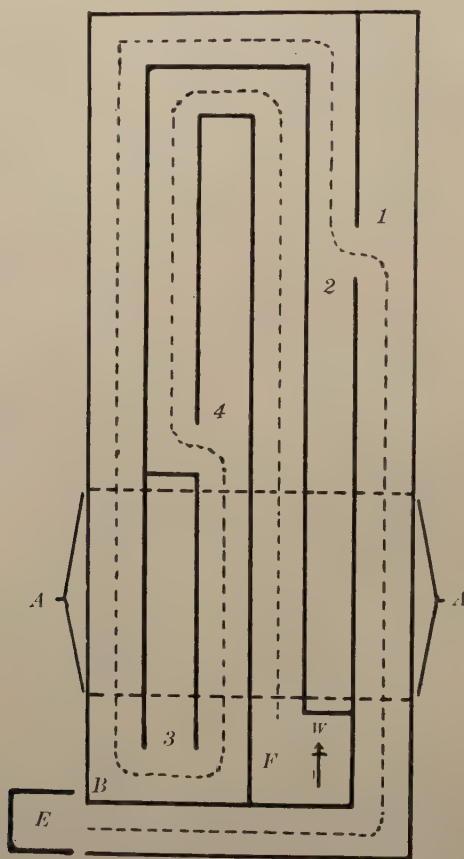


FIGURE 3—Labyrinth C. E, the entrance box; F, the food box; AA, the removable section.

they caused no marked inconvenience to the birds. There are four cul-de-sacs, *s*, *r*, *l* and *s* respectively. The maze is so constructed that the straightaways may be shortened without disturbing the interrelations of the pathways.

<sup>3</sup> The tests referred to occur in some unpublished work by Dr. Yoakum.

Figure 4 represents a ground plan of the cage and boxes. The nest boxes are at A; L is the general position of the labyrinths in the normal learning and memory series; E and F are the "entrance" and the "food" boxes respectively; SS is the door of the cage. It served also as a screen behind which the experimenter sat. Strings ran from the screen over the top of the cage and connected with sliding doors at E and F. At the close of each day's experiments, the maze was covered with boards to prevent any chance learning by the birds when walking about on top of the maze.

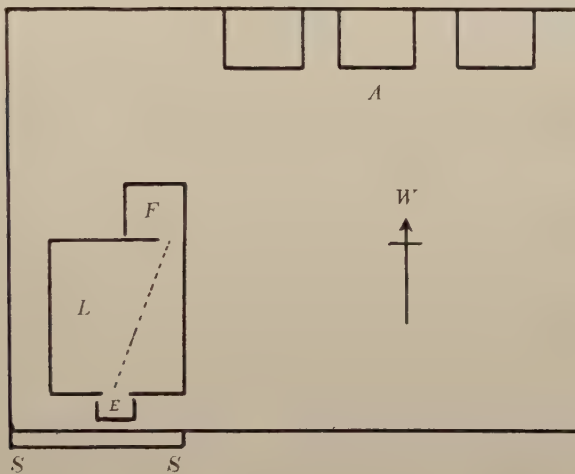


FIGURE 4—Ground plan of the cage and several boxes used.

Eight pigeons were used in the course of these experiments, four males (nos. 2, 4, 6 and 7) and four females (nos. 1, 3, 5 and 8). None were over a year old. Nos. 3 and 1 were not more than three months old when the work began. The birds were kept in the large outdoor wire cage described above, and in this cage the experiments were conducted.

Throughout the course of these tests work was begun sufficiently early in the morning to eliminate the most troublesome noises encountered in outdoor work in the city. The time of working served also to prevent shadows falling upon the maze.



The climate in this portion of the country is ideal for outdoor work. The regular experiments were never interfered with by bad weather.

The preliminary tests, which were given to all of the birds, trained them to go directly from E to F,—no partitions had as yet been placed in the maze. This training resulted in the establishment of an association between the maze and getting food. As a result, the first trials in the regular experiments were influenced by as strong a motive to thread the maze as were the immediately subsequent ones. Again, the habit which was formed of going directly across the box was one that had to be broken up when the partitions were placed in the maze. As soon as a pigeon had entered F, the door separating F from the maze was dropped in order to prevent retracing. This retracing was not prevented in Rouse's work.<sup>4</sup> What the exact result may be, it is impossible to say. At the close of these preliminary tests, work with pigeons nos. 5 and 8 was discontinued. However they were handled regularly every night and morning in order to prevent them from becoming wild again.

Throughout both the preliminary and the regular tests, the birds were given three trials daily. The exact pathways followed were represented upon a small plan of the maze.

#### HABITS IN LABYRINTH A

*I. First series,—normal learning records.* The results for this series are recorded in table I. An inspection of this will reveal a typical learning curve. Both times and errors gradually diminish until the final values are reached.<sup>5</sup> There is but slight variation in the time records toward the last. This is due to the simplicity of the maze and to the shortness of the runs. The pigeons never became automata. Although they made the runs rapidly and without a pause, they were constantly on the alert in passing alleys. The number of trials, however, was hardly sufficient to produce automatism. It is a point worth noting

<sup>4</sup> Loc. cit., p. 592.

<sup>5</sup> In this paper the term "error" designates, perhaps as in Porter's paper:<sup>6</sup> (1) every entrance into a cul-de-sac; (2) every turning back from its exit, when within a blind alley; and (3) all returns toward E over the true pathway. These three classes of errors are counted of equal value. No distinctions are made between errors on the basis of the distance covered in making them.

<sup>6</sup> Porter, J. P. Further Study of the English Sparrow and Other Birds. *Amer Jour. of Psychol.*, 1906, vol. 17, p. 253.

in this connection that throughout the entire course of these experiments the birds remained very alert and sensitive to unusual stimuli. Those affecting the senses of vision and hearing were particularly effective.

TABLE I  
LEARNING RECORDS FOR LABYRINTH A

No. of Test	Av. E.	M. V.	Av. T. Secs.	M. V.	No. of Test	Av. E.	M. V.	Av. T. Secs.	M. V.
1	6.1	6.6	131.6	146.4	9	.1	.8	20.	15.
2	1.5	1.1	31.5	13.1	10	0	0	21.	8.
3	1.6	1.	34.1	16.5	11	0	0	13.8	5.3
4	1.6	1.6	31.	21.3	12	0	0	12.6	4.5
5	.5	.5	17.	6.	13	0	0	16.6	11.7
6	1.8	1.5	20.6	8.	14	0	0	10.1	4.2
7	.1	.2	22.1	7.5	15	0	0	9.5	3.5
8	.5	.6	29.5	25.					

Rouse, working with a maze identical with labyrinth A, save that the partitions were of wire, gave preliminary tests in the same manner as did the present writer. However, during these and the regular experiments but one trial a day was given, as opposed to the three in the present experiments; and the times alone were recorded. Rouse's results vary considerably from those presented in this paper. Although this may be accounted for by differences in method and apparatus, the fact is important in that the present results were obtained with apparatus similar to that used in other work on animal behavior and thus afford a more satisfactory basis upon which to ground a comparative estimate of the pigeon's learning ability. An inspection of Rouse's table for this maze <sup>7</sup> shows that the average time curve for six birds begins very much higher, descends more slowly, and never reaches as low a minimum as the curve that might be drawn from the data in table I of this paper. It is thus apparent that vision from alley to alley must have served to lengthen the time in comparison with the results obtained by the present writer. Indeed, Rouse calls attention to the attempts of his pigeons to butt through the partitions in the first part of the maze and later to turn before the end of a given alley was reached.

<sup>7</sup> Op. cit., p. 589.

No such behavior was noted in the present experiments with wooden partitions. Head-on collisions with the walls never occurred. Aside from this comparison of time records nothing can be said with regard to the learning ability shown in the two sets of experiments. Rouse does not state at the end of which trial his birds had learned the problem. He gave, however, seventeen trials under uniform conditions. But the time record was reduced until the last, and it is difficult to say what comparative conclusions may be drawn.

*II. Second series,—memory records.* At the close of the fifteenth trial with labyrinth A, pigeons nos. 3, 4 and 6 were dropped from the course of the experiments, while the others were continued in labyrinth B. Nos. 3, 4 and 6 were handled and fed regularly each morning. At the expiration of twenty-nine days, they were again tested in labyrinth A.

The results of these tests are given in table II. It will be noticed that pigeon no. 4 made no errors and continued perfect for fifteen trials. No. 3 made five errors the first trial and was perfect thereafter. All of these errors were those of returning over the true pathway. The wrong alley was never entered. No. 6 was nervous upon being placed in E. Passing into the maze, he turned back and entered the second alley. This served to increase his confusion and for the next two trials he became worse. On the fourth trial, i.e., at the beginning of the second day, he was perfect and remained so until the thirteenth trial when, for some unknown reason, one error was made. These results justify the conclusion that the pigeon's memory (using the term in its biological sense) for this grade and type of problem is practically perfect after the lapse of four weeks.

Rouse gives no quantitative results for experiments upon memory. He tested it, however, and his conclusion is that associations are permanent for some weeks.

Porter,<sup>8</sup> in his experiments with birds, made some memory tests upon one vesper sparrow, a cowbird, and an English sparrow. The birds had learned a maze little if any more complex than the present one in from twenty to thirty trials. After a lapse of thirty days ten trials were given and no bird was perfect. From Porter's method of recording results, it is impossible to say how many perfect runs were made in the course of the ten

<sup>8</sup> Op. cit., p. 256.



TABLE II  
MEMORY TESTS FOR LABYRINTH A

No. of Test	Animals					
	No. 3		No. 4		No. 6	
	T.	E.	T.	E.	T.	E.
1	90"	5	6"	0	42"	2
2	10"	0	7"	0	38"	4
3	7"	0	5"	0	88"	8
4	12"	0	5"	0	6"	0
5	6"	0	7"	0	8"	0
6	7"	0	5"	0	5"	0
7	10"	0	10"	0	9"	0
8	12"	0	8"	0	6"	0
9	6"	0	9"	0	6"	0
10	7"	0	5"	0	7"	0
11	6"	0	5"	0	9"	0
12	6"	0	5"	0	10"	0
13	6"	0	14"	0	20"	1
14	7"	0	7"	0	10"	0
15	6"	0	7"	0	10"	0

trials. But it will suffice for our purpose to note that errors in the "average" columns persist through the tenth trial for one bird and through the eighth trial for the other two. A more detailed examination of the results will convince the reader that the records for Porter's birds do not indicate so good a memory as do the records presented here for pigeons.

#### HABITS IN LABYRINTH B

*I. First series,—normal learning record.* Five pigeons were used in this maze: nos. 1, 2, 5, 7 and 8. Of these nos. 5 and 8 were new to the problem of maze running. Tests with them had been discontinued at the close of the preliminary work with the hope that results might be obtained upon the value of previous training in the subsequent learning of a similar problem.

The results presented above for labyrinth A indicate that it is quickly and easily learned by the pigeon. Quite the contrary is the case with labyrinth B, figure 2. The description of this maze has already been given, but a few of its relations to A may be pointed out here. In A the first turn to the left means success; in B, it means entrance into blind alley no. 1. The

second blind alley is the same in each. Blind alley no. 3 in B corresponds to free passageway in A and necessitates a turn to the left in order to avoid it,—the passageway in A is made by a turn to the right. Blind alleys nos. 4, 5 and 7 in B have no corresponding ones in A. They were very seldom entered,

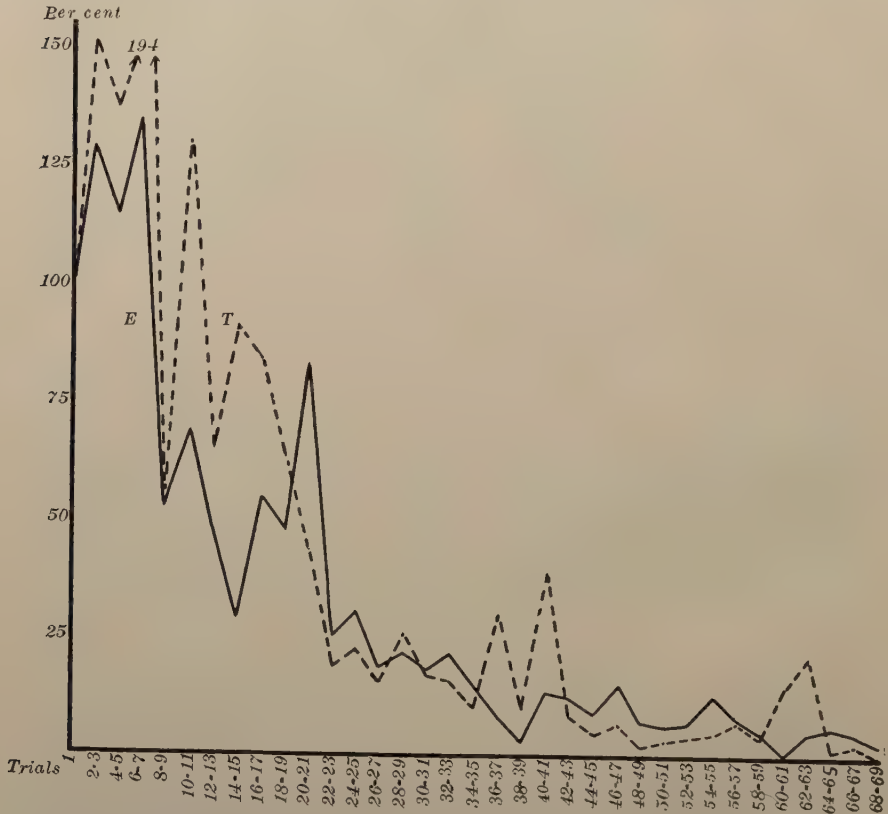


FIGURE 5—Graphs from the data of table III, labyrinth B. T, the time curve; E, the error curve.

but served to confuse the pigeon by a multiplicity of possible pathways. Especially when a bird was approaching alleys nos. 5 and 6, where three possible pathways were presented, it would pause and peer into each. Blind alley no. 6 in B is paralleled by the open alley to the food box in A. Among these alleys in B, nos. 1, 3 and 6 were those which occasioned the greatest difficulty in learning.

TABLE III  
RECORDS FOR LABYRINTH B

No. of Test	Av. E.	M. V.	Av. T. Secs.	M. V.	No. of Test	Av. E.	M. V.	Av. T. Secs.	M. V.
1	5.8	4.1	131.2	77.9	35	1.	1.2	26.6	12.5
2	12.	10.4	293.8	205.9	36	.6	.7	14.2	11.8
3	2.8	1.3	95.2	95.7	37	.4	.7	14.2	1.
4	7.4	4.4	228.2	117.4	38	0	0	14.	1.6
5	6.	2.4	125.8	54.	39	.4	.7	26.	7.6
6	11.2	8.2	332.	236.	40	1.	1.6	73.	89.6
7	4.4	2.	161.6	115.9	41	.6	.7	40.4	28.6
8	3.2	2.	94.8	102.8	42	.8	.9	24.2	8.6
9	3.	.6	49.	25.2	43	.6	.7	16.	7.2
10	3.8	2.5	235.6	197.3	44	.6	.7	13.	3.2
11	3.2	1.9	123.4	71.2	45	.4	.4	19.6	5.9
12	2.8	2.8	58.4	38.6	46	.6	.7	14.8	2.9
13	2.8	2.4	121.	74.4	47	1.2	1.	22.	11.2
14	1.2	1.	128.6	137.9	48	.8	.6	13.8	1.
15	2.	.4	114.8	106.1	49	.2	.1	11.6	.7
16	2.2	1.8	141.4	131.4	50	.2	.1	13.	2.
17	4.2	2.6	83.6	82.7	51	.6	.7	15.2	4.3
18	2.1	1.8	82.2	85.5	52	.4	.3	17.	5.2
19	3.6	2.3	94.	85.6	53	.6	.9	13.4	1.9
20	2.1	1.8	47.6	39.3	54	1.4	1.2	23.	10.8
21	3.8	1.7	79.2	73.	55	.2	.1	10.6	.7
22	.8	.7	25.	6.4	56	.2	.1	10.8	1.4
23	2.2	2.2	37.4	32.2	57	.8	1.2	31.	21.2
24	.8	.9	27.6	13.5	58	.4	.6	16.2	7.1
25	2.8	1.4	63.8	50.4	59	.2	.1	12.8	2.8
26	.4	.6	22.6	7.7	60	0	0	44.	42.4
27	1.8	1.	36.2	16.6	61	0	0	15.2	4.6
28	1.6	1.2	57.8	56.	62	.2	.1	11.8	2.9
29	1.	.8	26.2	11.4	63	.2	.1	12.6	3.1
30	.8	.9	22.2	11.5	64	.6	.7	11.2	3.5
31	1.4	1.2	39.	27.2	65	.2	.1	10.	1.2
32	1.6	1.5	33.4	16.6	66	.2	.1	13.8	5.3
33	1.	.8	25.4	8.	67	.2	.1	11.2	3.2
34	.8	.6	17.6	5.1	68	.2	.1	9.5	2.5

Table III presents the average times taken and the average errors made in learning this maze. It will be seen from this and the graphic representations in figure 5<sup>a</sup> that decrease in

<sup>a</sup> The graphs represented in figures 5, 6, 7, and 9 were constructed by the following method: The minimal time average, e.g., was subtracted from each time average thus giving the surplus values to be eliminated. In order to shorten the curve to a convenient length and to reduce the irregularities in it the surplus values were then averaged in pairs, omitting the first trial. The reason for not including this trial in the averages was that it was desired to show the relation of subsequent learning to the record first established. The results obtained by so manipulating the surplus values were now thrown into percentages, the first trial being rated as 100%. These percentages were then plotted. It was thought advisable to plot in terms of percentages in order that the time and the error graphs might be compared directly.



time does not really begin before the eleventh trial and decrease in errors not before the seventh trial. In figures 6 and 7 the curves again reveal the same characteristic. In the time curve for pigeons nos. 5 and 8 (fig. 6) there is no permanent

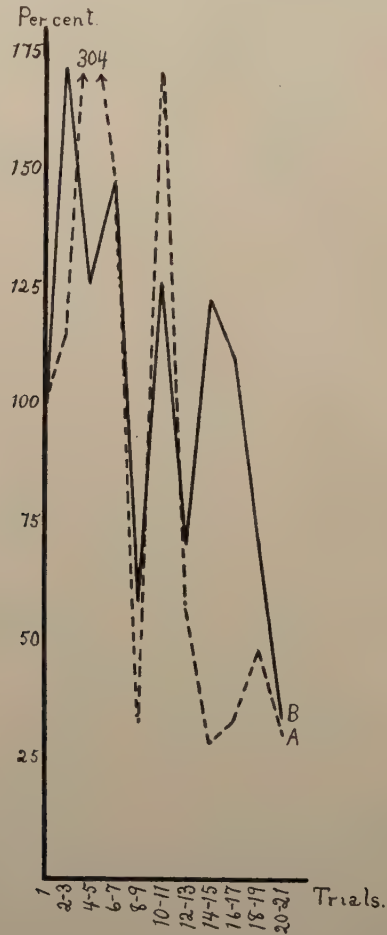


FIGURE 6—Time graphs for the first twenty-one trials of pigeons nos. 1, 2, and 7 (A) and nos. 5 and 8 (B) in labyrinth B.

descent before the sixteenth trial. The error curve (fig. 7) drops permanently after the sixth trial. The time curve (fig. 6) for pigeons nos. 1, 2 and 7 falls after the tenth trial; and the error curve (fig. 7), after the sixth. These are quite unusual

learning records. The conventional graphs show almost an immediate descent. What then is the explanation of the present results and what are their implications?

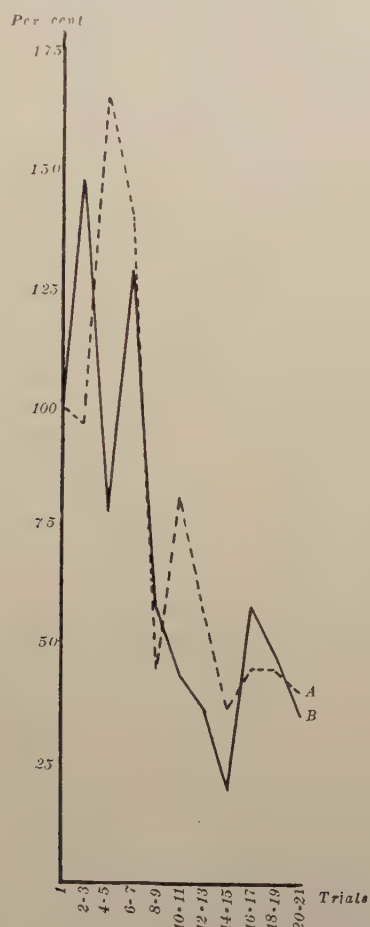


FIGURE 7—Error graphs for the first twenty-one trials of pigeons nos. 1, 2, and 7 (A) and nos. 5 and 8 (B) in labyrinth B.

Two reasons might be advanced in general for the maintenance of the learning curve at or about a certain height in experiments with mazes related as A and B. (1) The blind alleys in the two labyrinths are such that the habits acquired in A interfere with the learning of B. The persistence of acquired

co-ordinations, except when these are caused to disintegrate rapidly by severe punishment, which was not the case in the present instance, will keep the learning curve high. Pigeon no. 2, e. g., never permitted the average error record to drop below .2. He practically always entered the first cul-de-sac. Several times he passed its entrance and went at least a third of the way through the maze only to return, make the error, and then continue correctly. The persistence of old habits, though, is not the cause of that characteristic of the present curves which we are now discussing, for although pigeons nos. 5 and 8 had no old habits carried over from A to lead them astray, their curves are similar to the others. Since, then, the characteristic

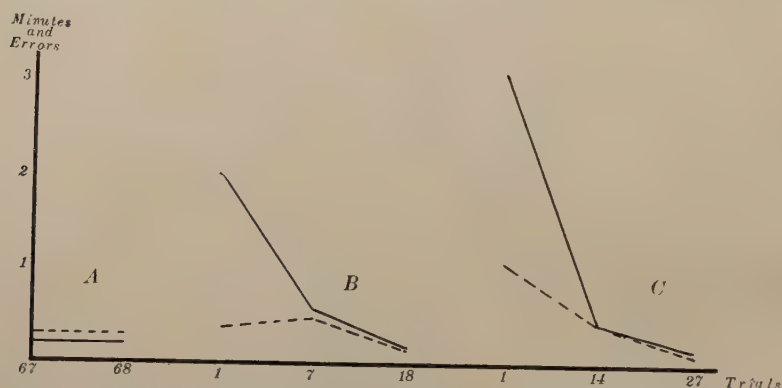


FIGURE 8—Time (-----) and error (————) graphs for the rotation tests. A, the last two trials of normal learning; B, rotation of 90°; C, rotation of 270°.

in question is not due to previous training and since it is not a necessary attribute of the pigeon's learning records—witness Rouse's results and those presented above for labyrinth A—it must be due to a peculiarity of the maze itself, viz., its complexity. This explanation is strengthened very much by the fact that the learning curves for labyrinth C, fig. 9, are of the same nature as those for B.

What is here presented, then, by way of an hypothesis, is a criterion by which to judge of the complexity of a maze or other problem in relation to an animal's ability to learn it. The greater this complexity, the longer will the curve be maintained at or above a certain point which is determined by a set of fairly easily ascertainable facts and which is usually the

height of the curve at the first or second trial. The learning curve, e. g., of a problem the chief points of which an animal has failed to master, would never descend permanently below the height to which reference has just been made. The mere

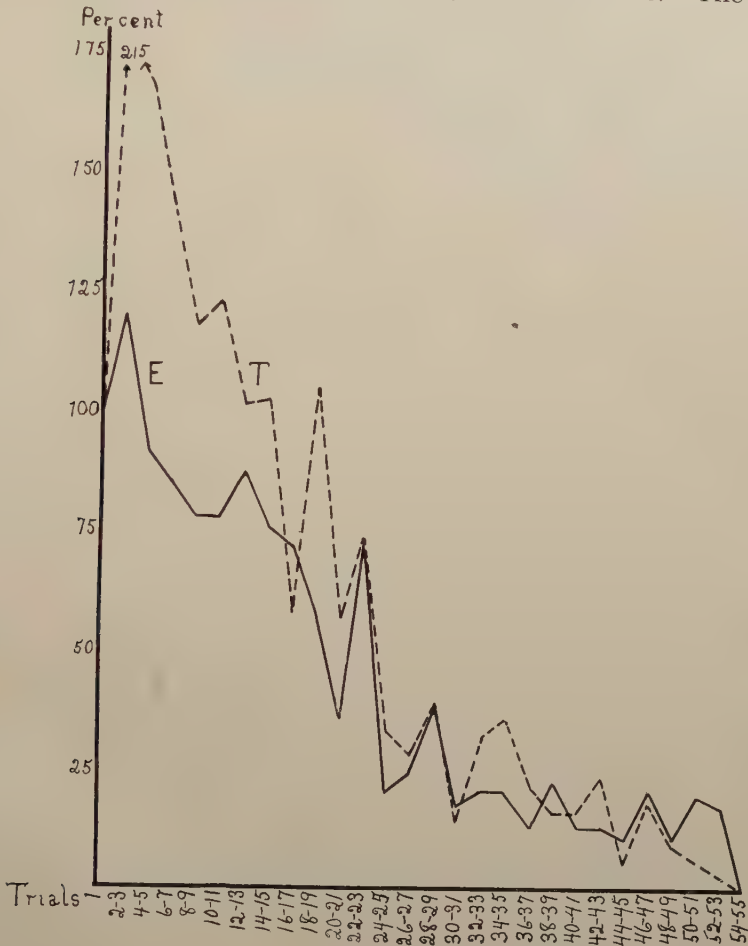


FIGURE 9—Graphs from the data of table VII, labyrinth C. T, the time curve; E, the error curve.

fact that an animal has made all of the possible errors is not sufficient to produce a lowering of the curve. If such were the case, it would be difficult to get a graph that would not descend. The animal must recognize an error as an error and



thus avoid it. There is no necessity to assume conscious as opposed to automatic recognition. The fact that an animal's behavior in successive trials stamps a certain pathway as untrue is sufficient.

In the present experiment when this point was reached, i. e., when the curve began to fall permanently, the errors were eliminated as follows: After those of returning over the true pathway had gone, there followed a stage in which the errors of entering blind alleys nos. 1, 3 and 6 were almost the only ones made. Here a curious, although not necessarily a totally unpredictable fact came to light. The tendency to make errors at 1 and 6 was stronger than at first. The peculiar nature of these cul-de-sacs is that each precedes an exactly similarly situated alley which is the true one. Thus the reaction called for is a control of the impulse to turn until a few more inches shall have been traversed. To the writer and other observers, it appeared that after the pigeon had learned that the required turns were to the right and left respectively, it took the first opportunity to make such reactions rather than control the impulse a little longer. Such behavior indicates the influence of a kinaesthetic factor, a visual one, or both. In most cases the error at cul-de-sac no. 3 was the next eliminated and was followed in order by those at nos. 6 and 1.

The data which were secured upon the question of the value of previous training in the subsequent learning of a new maze are as follows: Pigeons nos. 5 and 8 learned the problem equally as soon as did nos. 1, 2 and 7. The curves, figs. 6 and 7, for the two groups of birds, however, reveal marked differences. Neither the time nor the error graphs for pigeons 5 and 8 rise as high as do the respective graphs for pigeons 1, 2 and 7. Yet the time curve for the latter group descends permanently sooner than the corresponding curve for the former group.

The most probable conclusions to be drawn from these facts would link up previous training and subsequent learning as follows: (1) The habits acquired in labyrinth A by birds nos. 1, 2 and 7 *interfered* with their learning of B and resulted in a slow elimination of errors. (2) The training in A made it possible for nos. 1, 2 and 7 to reduce their time records permanently sooner than did nos. 5 and 8. Just why previous training should have had this effect on the time records the writer is

unable to say definitely. It may be because with training the birds became less susceptible to such distracting stimuli as are incident to novelty of surroundings. It may be that training resulted in the birds acquiring an attitude similar to self-confidence in man.

In figs. 5 and 9 it will be noticed that the error curve in each case descends more rapidly at first than does the time curve. This is just the reverse of the results obtained by Mrs. V. C. Hicks<sup>10</sup> for rats. It is in harmony with the view already expressed in this paper as to the complexity of mazes B and C to explain the present relation between the time and the error curve as due to the confusion and consequent slowing down of the pigeon when it is confronted with a problem so near the maximum of difficulty. As soon, however, as the bird regains "self-confidence," it speeds up and the curve drops rapidly in comparison with errors. From this point on, time and errors run along approximately together.

*II. Second series: Rotation of the maze.* It is a familiar fact in work on animal behavior that when a maze, or other problem box with which an animal has been trained, is rotated in reference to the environment, confusion results and a more or less extended period of relearning is necessitated. The work on this problem with birds has been done by Porter<sup>11</sup> and Watson.<sup>12</sup> Both found that rotation caused confusion. Neither, however, made a detailed analysis of it.

In the present experiments three different degrees of rotation were tested, viz.,  $90^\circ$ ,  $270^\circ$ , and  $360^\circ$  to the left. Some birds were confused at  $90^\circ$ , but perfect at  $270^\circ$ . For others the reverse was true—or very nearly so, there being a slight confusion at  $90^\circ$ . One bird was confused at both positions. After sixteen days training in these two positions, all the birds were perfect at  $360^\circ$  rotation.

Fig. 8 summarizes graphically the results of these tests. Table IV presents numerically the results obtained by rotating the maze  $90^\circ$ . It is to be noted that a considerable confusion is indicated by both the average times and the average errors.

<sup>10</sup> Hicks, V. C.; The Relative Values of the Different Curves of Learning. *Jour. Animal Behavior*, 1911, vol. I, p. 145.

<sup>11</sup> Op. cit., pp. 256-7.

<sup>12</sup> Watson, J. B.<sup>9</sup> Behavior of Noddy and Sooty Terns. Carneg. Instit. Publ., 1909, no. 103, pp. 254-5.

Only after the tenth trial was the normal average error record of .2 regained. It then remained constant until the end. The average time record became normal after the fourteenth trial. Those pigeons that became confused hesitated, upon entering the maze, and invariably made an error at cul-de-sac no. 1. The error at no. 2 was also made as were those of turning back over the true pathway. An error at no. 6 was made twice—once by pigeon no. 7 on the eighth trial, again by pigeon no. 8 on the seventh trial.

TABLE IV  
MAZE ROTATED 90° TO THE LEFT

No. of Test	Animals											
	No. 1		No. 2		No. 5		No. 7		No. 8		Av.	
	T.	E.	T.	E.	T.	E.	T.	E.	T.	E.	T.	E.
1	18"	1	9"	1	37"	7	11"	0	20"	1	17."	2.
2	13"	0	22"	5	20"	1	8"	0	40"	3	20.6"	1.8
3	11"	0	8"	1	81"	8	9"	0	30"	1	27.8"	2.
4	9"	0	13"	2	24"	2	21"	3	52"	4	23.8"	2.2
5	7"	0	10"	1	11"	1	22"	1	15"	1	13."	.8
6	8"	0	9"	1	10"	0	15"	0	17"	1	11.8"	.4
7	12"	0	10"	1	20"	0	17"	0	85"	2	28.8"	.6
8	10"	0	11"	1	20"	0	15"	1	12"	0	13.6"	.4
9	13"	0	10"	1	22"	0	12"	0	18"	0	15."	.2
10	10"	0	10"	1	12"	0	10"	0	15"	1	11.4"	.4
11	8"	0	7"	1	12"	0	15"	0	11"	0	10.6"	.2
12	7"	0	10"	1	8"	0	14"	0	10"	0	9.8"	.2
13	34"	0	7"	1	14"	0	20"	0	26"	0	20.2"	.2
14	11"	0	10"	1	22"	0	13"	0	14"	0	14."	.2
15	11"	0	7"	1	9"	0	12"	0	18"	0	11.4"	.2
16	9"	0	9"	1	15"	0	12"	0	12"	0	11.4"	.2
17	9"	0	10"	1	10"	0	10"	0	10"	0	9.8"	.2
18	8"	0	9"	1	13"	0	11"	0	9"	0	10."	.2

If the conditions of the experiment are kept well in mind, the following explanation may not seem amiss: Assuming for the time that visual sensations from *without* the maze are influential in guiding the pigeon in its reactions, the tendency will be to head directly north (*vide supra*, fig. 2) when the maze is rotated. But this is sure to result in the errors, which were actually made. After the second alley is passed, in the rotated maze, theoretically, the tendency will be toward the west and the error at no. 6 will be avoided. The results show that this

error was avoided, save twice. But this is not all. As the reader has doubtless observed, it is difficult to say whether or not pigeons nos. 1, 2 and 7 were confused by the rotation. An explanation of this will be offered below. It is not to be assumed that the visual cues here in question were acting alone. They might be modified by kinaesthetic factors. The extent to which it is probable that these latter were present will be touched upon later in this paper.

Circumstances did not permit the writer to rotate the environment with the maze. Had this been done the disturbance due to the change of external visual cues in relation to the maze would have been avoided. What the pigeon's behavior would have been under those circumstances cannot be stated with certainty. It is probable that there would have still been individual variations depending upon the cues in use by the several birds. But certainly if the analysis given above and continued later in this paper is valid, those pigeons dependent upon external visual cues would not have been disturbed in their reactions.

Table V gives the results for a rotation of  $270^{\circ}$  to the left from the position in which the normal learning record was obtained. The confusion was greater in this case than in the one above. A normal error record was not reached until after the eighteenth trial; the time record was reduced until the last. If the explanation ventured in the above case of the influence of the external visual factors were true, it would only be in evidence here as a tendency to go slowly or even to turn back. It is difficult to say whether such tendencies were present in unusual force or not. However, the diary record—kept before this explanation was thought of—contains much reference to “going slowly” and to constantly “turning back.” A marked peculiarity of this table is that pigeon no. 5 made only one error (in the fifteenth trial), and it could hardly have been due to the rotation.

After this series of tests the maze was rotated to  $360^{\circ}$ , Table VI. Nine tests were made, but no confusion was present. As will be seen later (*vide infra*, pp. 298, 299), this may indicate either that the original co-ordination persisted for sixteen days or that between the two tests the birds had acquired a system of cues that would save them from any future confusion.



TABLE V  
MAZE ROTATED 270° TO THE LEFT

No. of Test	Animals											
	No. 1		No. 2		No. 5		No. 7		No. 8		Av.	Av.
	T.	E.	T.	E.	T.	E.	T.	E.	T.	E.	T.	E.
1	250"	13	17"	2	10"	0	26"	0	22"	1	65."	3.1
2	68"	4	12"	2	11"	0	19"	1	17"	1	25.4"	1.6
3	12"	0	9"	1	9"	0	20"	1	19"	0	13.8"	.4
4	15"	1	40"	5	14"	0	35"	2	40"	2	28.8"	2.
5	23"	1	17"	1	15"	0	17"	2	43"	3	23."	1.4
6	18"	2	17"	1	14"	0	14"	1	18"	0	14.8"	.8
7	14"	0	14"	2	9"	0	36"	0	59"	1	26.4"	.6
8	11"	0	35"	3	10"	0	13"	0	46"	2	23."	1.
9	12"	0	11"	2	8"	0	12"	0	16"	0	11.8"	.4
10	30"	1	14"	1	49"	0	33"	1	205"	8	66.2"	2.2
11	9"	0	11"	1	11"	0	15"	0	87"	1	26.6"	.4
12	7"	0	9"	1	10"	0	10"	0	30"	0	13.2"	.2
13	8"	0	11"	1	9"	0	18"	0	26"	0	14.4"	.2
14	13"	0	8"	0	10"	0	24"	0	72"	2	25.4"	.4
15	8"	0	10"	1	26"	1	14"	0	20"	0	15.6"	.4
16	62"	5	24"	1	44"	0	18"	0	15"	0	32.6"	1.2
17	22"	1	21"	1	28"	0	13"	0	19"	0	20.6"	.4
18	9"	0	20"	1	24"	0	11"	0	28"	1	16.4"	.4
19	10"	0	15"	1	16"	0	28"	0	24"	0	18.6"	.2
20	9"	0	17"	1	11"	0	12"	0	15"	0	12.8"	.2
21	9"	0	17"	1	11"	0	9"	0	14"	0	12."	.2
22	9"	0	16"	1	12"	0	11"	0	40"	0	17.6"	.2
23	10"	0	16"	1	13"	0	11"	0	20"	0	14."	.2
24	7"	0	22"	1	9"	0	10"	0	18"	0	13.2"	.2
25	45"	1	20"	0	21"	0	15"	0	13"	0	22.8"	.2
26	10"	0	23"	1	15"	0	11"	0	15"	0	14.8"	.2
27	11"	0	15"	1	9"	0	8"	0	12"	0	11."	.2

The explanation which was postponed above concerned the question as to why some of the birds were not confused by the rotation. The only one which seems warranted to the writer by these experiments is as follows: It seems very probable that the two main sensory cues used both in learning the maze and in running it after it is learned are visual and kinaesthetic sensations. The visual cues may be again sub-divided into those arising from within and those arising from without the maze (an example of the latter would be the relation of the walls and boxes of the large cage to the maze). This limitation of the number of cues is based: (1) Upon Rouse's conclusion that tactual sensations are non-functional; (2) upon the common belief that olfaction is not present in birds; and (3) upon the

knowledge that those auditory sensations present were not of such a regular nature as to be available for guidance. Now it is hardly to be expected that rotation would confuse an individual save as it disturbed the inter-connection of cues which

TABLE VI  
MAZE ROTATED 360° TO THE LEFT

No. of Test	Animals											
	No. 1		No. 2		No. 5		No. 7		No. 8		Av.	
	T.	E.	T.	E.	T.	E.	T.	E.	T.	E.	T.	E.
1	8"	0	9"	1	9"	0	10"	0	10"	0	9.2"	.2
2	8"	0	9"	1	11"	0	8"	0	10"	0	9.2"	.2
3	9"	0	10"	1	10"	0	8"	0	11"	0	9.6"	.2
4	8"	0	8"	1	8"	0	9"	0	12"	0	9."	.2
5	8"	0	9"	1	8"	0	10"	0	11"	0	9.2"	.2
6	7"	0	9"	1	9"	0	8"	0	12"	0	9."	.2
7	9"	0	9"	1	11"	0	15"	0	17"	0	12.2"	.2
8	8"	0	12"	1	9"	0	9"	0	11"	0	9.8"	.2
9	10"	1	8"	1	8"	0	12"	0	11"	0	9.8"	.4

had been established prior to the change of position. In general, an inter-connection is possible, (a) between cues of the same system, as the external visual cues; or (b) between different systems within the same sense modality; or, finally (c) between the cue systems of different sense modalities, as visual and kinaesthetic. With these claims granted, our conclusion is that the cues of most importance to the individuals that were not confused in the 90° and 270° rotations were visual sensations arising from *within* the maze, because the inter-connection of these alone would not be disturbed by rotation. For the confused individuals, visual sensations arising from *without* the maze were the dominant cues. (In both cases, as will appear below, kinaesthetic factors probably exerted an influence, the exact nature of which is uncertain.) The full significance of the above statements comes out in the answer to another question.

How does it happen that the birds (nos. 1, 2 and 7) that were confused little, if any, in the 90° rotation were confused greatly in the 270° position, while, on the other hand, pigeon no. 5, who was confused in the 90° rotation, was not in that of 270°?

The preceding analysis makes the following answer necessary: Those birds that passed from confusion to lack of confusion, or *vice versa*, with a change in the degree of rotation of the maze, must in some manner have changed the system of cues upon which they were depending. Pigeon no. 5, e. g., must have been relying upon visual sensations from without the maze at the time when the  $90^\circ$  rotation was made, because only on this basis could the inter-connection of cues have been disturbed by the change. During the tests at the  $90^\circ$  rotation, in place of filling in the gaps (however large or small) in his system of cues with other external visual "landmarks" or with the old ones now reconstructed, pigeon no. 5 did one of two things: He either left the gap unfilled and relied upon the remaining cues, or else he filled it with visual cues from within the maze. Hence when the  $270^\circ$  rotation was made, his reactions were not confused.

The case of pigeons nos. 1, 2 and 7 is slightly different. What seems the most probable explanation of their behavior is as follows: In the normal position of the maze, these birds relied upon visual cues from within the labyrinth and upon some from without. These latter were of such a nature as not to be noticeably changed by the  $90^\circ$  rotation. (An example of these would be the screen behind which the experimenter sat. An inspection of fig. 4 will aid in understanding the statement that all of labyrinth B was not behind the screen—a part projected to the north, without, however, exposing the experimenter to the bird's view. This being the case, a  $90^\circ$  rotation would not change the relative position of the screen and the maze nearly so much as a  $270^\circ$  rotation.) Hence there was little confusion, if any, at this position. However, at  $270^\circ$  the external visual cues, e. g., the screen, were so changed in relation to the maze as to cause much disturbance in the birds' reactions. Again, two alternatives were open to the birds: they might either replace the changed "landmarks" with partially or entirely new ones, or they might fall back upon the cues that yet remained. Which was done cannot be stated.

How, now, are the perfect records for all the birds at the  $360^\circ$  rotation to be explained? The present experiments unfortunately do not provide data for a complete answer to this question. Two explanations seem equally possible to the writer: (1) The

co-ordinations used sixteen days before may have persisted unimpaired by the intervening training. In this case, the instance would be one of (organic) memory. (2) The pigeons may each have succeeded, during the intervening training, in acquiring a system of cues which would be undisturbed by *any* degree of rotation. These two theories should have been tested by noting the effects on the birds of degrees of rotation as yet untried, as well as by repeating tests for  $90^\circ$  and  $270^\circ$ .

The two hypotheses just advanced cover the case of pigeon no. 8, who was confused at  $90^\circ$  and  $270^\circ$ , but who was perfect at  $360^\circ$ . Comparative psychologists are already familiar with the view that an animal may use one set of cues in learning a maze and another in running it after learning is completed. But so far as the present writer knows facts have never before been presented in support of the hypothesis here presented, viz., that an animal may change its system of cues from time to time in response to the varying demands of a situation. This view of the matter is of more than passing interest in that it at least suggests the complexity of the animal mind for types as high as the pigeon. Most investigations in animal behavior (particularly in maze problems) lay chief stress upon the simplicity of animal consciousness. The other alternative should not be overlooked and neglected.

#### HABITS IN LABYRINTH C

*Tests for kinaesthetic control.* Four pigeons, nos. 1, 2, 5 and 7 were tested in this labyrinth. All had gone through the tests in labyrinth B, and with the exception of no. 5, they had all been trained in A as well. Constant training had made the birds quite docile so that a maximum efficiency record might now be looked for. The results are given in Table VII and fig. 9. The long alleys in this maze were very confusing at first—the birds were constantly turning back before the ends of the alleys were reached. All were perfect in the 54th, 55th and 56th trials. Nos. 5 and 7 both made errors in the 57th trial. The cause of the former's errors is unknown. The latter apparently blundered because he was going too fast. The learning of this maze was accomplished a few trials earlier than in the case of B. However, the learning curve possesses essentially the same form as in the former case. This, as was pointed out above, lends much additional support to the hypothesis which would make



the number of trials during which the ordinate value fails to decrease permanently below the point reached in the first or second trial the measure of the complexity of a problem in relation to an animal's ability to learn it.

At the end of the 57th trial, the maze was shortened without disturbing the interrelations of the turns. The tests in this modified maze were continued for two days, and the results appear in Table VII.

TABLE VII  
LEARNING RECORDS FOR LABYRINTH C, AND TESTS FOR KINAESTHETIC CONTROL

No. of Test	Animals									
	No. 1		No. 2		No. 5		No. 7		Av.	
	T.	E.	T.	E.	T.	E.	T.	E.	T.	E.
1	140"	7	358"	9	180"	6	60"	0	184.5"	5.5
2	270"	8	158"	3	420"	4	660"	12	377."	6.7
3	720"	13	430"	10	330"	4	50"	0	357.5"	6.5
4	335"	6	310"	8	535"	10	67"	0	311.7"	6.
5	312"	4	233"	6	500"	7	43"	0	274."	4.2
6	103"	1	146"	7	507"	7	283"	4	259.5"	4.7
7	127"	3	264"	7	500"	7	103"	2	248.5"	4.7
8	43"	0	126"	3	341"	4	43"	0	138.2"	1.7
9	523"	8	201"	11	379"	8	58"	1	290.2"	7.
10	211"	5	237"	6	575"	7	152"	4	293."	4.5
11	225"	6	129"	5	103"	3	150"	3	151.7"	4.2
12	61"	1	65"	3	245"	5	252"	5	155.7"	3.5
13	330"	11	67"	1	345"	10	143"	3	221.2"	6.2
14	304"	7	271"	8	114"	2	127"	3	204."	5.
15	36"	1	63"	1	540"	12	65"	0	176."	3.5
16	384"	9	157"	1	83"	2	92"	2	179."	3.5
17	70"	1	62"	0	51"	1	67"	0	62.5"	.7
18	110"	2	131"	2	347"	6	260"	4	212."	3.5
19	62"	2	80"	2	232"	2	320"	6	173.5"	3.
20	205"	5	45"	1	260"	4	160"	1	167.5"	2.7
21	45"	1	48"	2	89"	1	89"	1	67.7"	1.2
22	245"	5	83"	2	260"	3	260"	4	212."	3.5
23	65"	1	73 "	1	62"	0	89"	1	72.2"	.7
24	85"	1	90"	2	48"	0	90"	1	78.2"	1.
25	86"	2	70"	1	47"	1	130"	2	83.2"	1.5
26	48"	1	63"	2	43"	0	43"	0	49.2"	.7
27	167"	5	44"	1	64"	1	96"	2	92.7"	2.2
28	48"	1	50"	2	50"	1	195"	4	85.7"	2.
29	192"	6	37"	1	94"	2	57"	0	92.5"	2.2
30	51"	1	31"	0	39"	0	53"	0	43.5"	.2
31	73"	1	40"	1	60"	1	63"	0	59."	.7
32	40"	0	30"	0	130"	3	122"	2	80.5"	1.2
33	113"	2	28"	0	95"	3	60"	0	74."	1.2
34	40"	0	50"	1	200"	4	150"	2	110"	1.7
35	84"	2	35"	1	60"	0	60"	0	59.7"	.7
36	41"	1	21"	0	150"	2	40"	0	63."	.7
37	42"	1	40"	0	53"	1	115"	2	62.5"	1.

TABLE VII—(continued)

No. of Test	Animals										
	No. 1		No. 2		No. 5		No. 7		Av.		
	T.	E.	T.	E.	T.	E.	T.	E.	T.	E.	
38	45"	1	32"	0	45"	0	50"	1	43."	.5	
39	68"	3	75"	2	43"	1	75"	3	62.2"	2.2	
40	55"	2	43"	2	90"	1	50"	0	59.5"	1.	
41	61"	3	18"	0	50"	0	42"	0	47.7"	.7	
42	30"	0	17"	0	130"	2	45"	0	55.5"	.5	
43	40"	1	45"	1	48"	0	160"	3	73.2"	1.25	
44	29"	1	40"	1	48"	2	40"	0	39.2"	1.	
45	33"	1	19"	0	43"	1	38"	0	33.2"	.5	
46	25"	0	20"	0	43"	2	120"	2	52."	1.	
47	85"	3	67"	3	70"	0	32"	0	63.5"	1.5	
48	38"	0	30"	1	60"	1	30"	0	39.5"	.5	
49	80"	2	35"	1	40"	1	28"	0	45.7"	1.	
50	100"	4	16"	0	32"	0	26"	0	43.5"	1.	
51	30"	1	50"	4	30"	0	25"	0	33.7"	1.25	
52	40"	0	35"	1	33"	0	31"	1	34.7"	.5	
53	32"	0	17"	0	50"	2	20"	0	29.7"	.5	
54	30"	0	15"	0	41"	0	20"	0	26.5"	0	
55	25"	0	20"	0	45"	0	30"	0	30."	0	
56	24"	0	25"	0	35"	0	22"	0	26.5"	0	
57	25"	0	18"	0	48"	1	30"	2	30.2"	.7	
Section removed from maze	1	19"	0	31"	2	30"	0	42"	2	30.5"	1.
	2	15"	0	*85"	10	22"	0	15"	0	34.2"	2.5
	3	*90"	4	25"	1	20"	0	17"	0	38."	1.5
	4	15"	1	40"	0	21"	0	55"	3	22.7"	1.
	5	18"	0	30"	0	30"	0	20"	0	24.5"	0
	6	18"	0	35"	0	31"	0	18"	0	25.5"	0

\* Very nervous, due to slip in transfer.

Although these records are not ideal, owing to disturbances which occurred on the first day with pigeons nos. 1 and 2, and owing to the brief period over which the training tests extended, the conclusions toward which they point are not uninteresting. If kinaesthetic cues were of more importance in negotiating turns than visual ones, this fact should manifest itself by the birds making errors at cul-de-sacs nos. 1 and 4 and butting into the end of the alley marked B.<sup>13</sup> Now an error at alley no. 1 was never made, while at some time every bird save pigeon no. 5 entered blind alley no. 4. Again, at no time did a bird butt into the wall at B. The conclusion must be that visual cues were of more importance than kinaesthetic ones for no. 5. With

<sup>13</sup> See figure 3.

the others kinaesthetic factors were of more importance in making the turn at alley no. 4; but elsewhere vision was the stronger.

This is quite in harmony with conclusions already reached in this paper. In the  $270^\circ$  rotation of labyrinth B, pigeon no. 5 was not confused, while the others were. We held at that time that no. 5 was guided by visual cues from *within* the maze and by a possible kinaesthetic factor which latter the present results rule out. The other birds were guided by visual cues from *without* the maze and by a possible kinaesthetic factor whose effectiveness the present results confirm.

The question now arises, why was no error made at alley no. 1? The only answer which suggests itself is as follows. Before the maze is shortened the alleys leading to cul-de-sacs nos. 1 and 4 are both fairly long—that leading to no. 1 being practically twice the length of the other. When the maze is shortened the alley to no. 4 is almost eliminated, while that to no. 1 remains several feet long. Practice in the complete maze was not continued long enough to make the kinaesthetic adjustments accurate for the exact distances to the turns, even if such adjustments could ever be attained. But it did suffice to acquaint the birds with the fact that fairly long runs were to be made in each case before a turn, i. e., they would go a certain distance relying upon kinaesthesia and then look about for the opening through which to turn. This procedure worked all right in the shortened maze save at alley no. 4. Here kinaesthesia carried the birds into the blind alley before they were ready to use vision.

Whether a more extended period of training would result in such a perfect kinaesthetic control as to drive the birds into alley no. 1 and against the end of alley B is more or less of an open question. Carr and Watson<sup>14</sup> in their tests on orientation in the white rat found such control in evidence. Yoakum obtained similar results in his work (unpublished) on kinaesthetic control in squirrels. The present writer is very much inclined to doubt whether any amount of practice would lead the pigeon to butt against the walls (if wooden) of the maze. It might, and undoubtedly would, lead some of the birds to neglect

<sup>14</sup> Carr, H. and Watson, J. B.: Orientation in the White Rat. *Jour. of Comp. Neur. and Psych.*, 1908, vol. 18.

the proper turns. These conclusions appear to be borne out by the experiments presented above for rotation. Visual cues seem always valuable to the pigeon. In this respect it differs markedly from squirrels and rats.

Watson<sup>15</sup> has placed on record observations which are confirmatory of the doubt expressed above. His experiments upon the behavior of the sooty terns in Porter's simple maze give a graph the irregularity of whose latter portion is similar to the curves in the present paper. Watson's comments upon the nature of the curve and upon automatic activity in the terns are well worth quoting here:

"If the time for idling, which is a characteristic mode of behavior and is not due to a lack of hunger, were taken out the curve as shown above would be much smoother and would lie very much nearer the base line. If the latter part of this curve be compared with the corresponding portion of a similar curve obtained from the rat in learning the Hampton Court Maze<sup>16</sup>, its extreme irregularity as compared with the rats' curve will at once be noticeable. *The terns never become the automata which the rats become.*" (Italics mine.)

#### CONCLUSIONS

The following conclusions seem warranted by the preceding experiments:

1. In respect to the rapidity with which maze problems are learned, the pigeon stands on a substantial par with the birds tested by Porter and the sooty terns tested by Watson; but it is superior to the noddy terns studied by the latter writer. The results for squirrels and rats to which reference has been made in the body of this paper indicate that these animals can learn a more complex maze in less time than the pigeon can learn a simpler one. It is evident that the pigeon does not form motor co-ordinations of the type demanded by a maze problem nearly so rapidly as do rodents. This statement does not mean to impugn the pigeon's intelligence! As Watson points out, it is doubtful whether human beings could equal the records made by his rats. What is intended is a specification of the pigeon's

<sup>15</sup> Watson, J. B.: The Behavior of Noddy and Sooty Terns. *Carneg. Inst. Publ.*, 1909, no. 103.

<sup>16</sup> Watson: *Kinaesthetic Sensations*, p. 100.



mental type and the consequent bringing out of the fact that this bird is not well adapted to maze work. This will be noted further in the fourth and fifth conclusions.

2. It is very probable that a criterion by which to judge of the complexity of a problem in relation to an animal's ability to solve it is to be found in the form of the learning curve. The greater this complexity, the longer will the curve fail to descend permanently below a certain height which will usually be the ordinate value of the graph at the first or second trial.

3. Memory (organic) for simple labyrinth problems is practically perfect for four weeks, where there has been no intervening training whatsoever. In this respect the pigeon seems slightly superior to the sparrows and the cowbird tested by Porter. After sixteen days, where there has been intervening training upon the same maze in various positions of rotation, the pigeons used in the present experiments all made perfect records. Whether this is to be interpreted as a case of organic memory or as the acquisition of a new system of cues which will prevent any confusion by rotation, the present experiments do not determine.

4. In learning the maze the pigeon is normally entirely dependent upon visual and kinaesthetic cues. The relative values of these vary from individual to individual. However kinaesthesia does not play as important a role in the mental life of the pigeon as in that of squirrels and white rats; and vision is of more importance than with the latter animals. Rouse<sup>17</sup> found that the pigeon can form auditory as well as visual associations. Although this was not tested in the present experiments, the fact did come out that the birds were very sensitive to sound.

5. The important thing that stands out as a result of the present experiments upon rotation, aside from the support which they give to the specific analysis of sensory control as this is stated in the fourth conclusion, is that the pigeon seems capable of changing its system of cues in response to the varying demands of a new situation.

<sup>17</sup> *Op. cit.*, pp. 593-597.

## NOTES

### SOME FEATURES OF BEHAVIOR IN THE COURTSHIP DISPLAY OF THE PALMATE NEWT (*Molge* *palmata* Schneid.)

BRUCE F. CUMMINGS

The Palmate Newt (*Molge palmata* Schneid.), widely distributed in Great Britain, but absent from Ireland, presents in its courtship display certain features of behavior to which particular attention has not yet been drawn. Sexual dimorphism is strongly marked, the male being handsomely colored along the sides of the body and possessing a very long, fine filament, extending beyond the end of the tail. Generally speaking the male follows the female through the water pressing his lips against her side or against her cloaca. When the sexual fever becomes more intense, the active little male rushes forward in front of the female and bars her progress. At the same time, he bends back the distal half of his tail and vibrates it at a wonderfully rapid rate, alongside the proximal half. The female will move away and, the male following, the performance is repeated. At the beginning of each of these spasms, the male hollows out one side of its body and bends it around towards the female. As the excitement dies down, the body assumes a straight position, though the tail with its caudal filament continues to vibrate. There are two features which must appear striking to any observer, particularly if he is firm in a faith in sexual selection. First, the display always takes place in front of the female. The male swims along by her side till he is in front, before displaying. Secondly, should the female, in the middle of a display, move away so as to be unable to see the male's tail vibrating, the male unbends his tail and turns it right around so as to vibrate it on that side which is in view of the female. In regard to the vibrating of the tail, too, it is suggestive to recall that *motion* in an object attracts the newt sooner than an object motionless. The female, if willing to be courted looks at the male with a dull hypnotic stare. It was once believed that the vibration of the tail set up a current in the water which carried the spermatozoa towards the female. This is now known to be incorrect.

In my opinion, the tail vibration is simply a method of eliminating a surplus of nervous activity stored up, at the sexual season, — is without any definite purpose. The question requires further analysis, however, and it is worth consideration. For example, the male bends its body towards the female. This movement brings the head and especially the cloaca nearer the female. Supposing that the male's body is curved around in that direction simply from sexual desire, it is clear that the tail can be bent and vibrated most easily on the inside of this curve, that is to say towards the female. No alteration in the side on which the tail vibrates is made without the preliminary spasm and bend of the body. Last spring, I had several ill-conditioned males which, through ill health, looked superficially as dull in color as females. On more than one occasion, I saw a male displaying in front of these animals. Whether this signifies that the female is recognized by sight alone, I cannot say. The evidence is insufficient.



## BREHM'S TIERLEBEN<sup>1</sup>

ROBERT M. YERKES

The famous work of Brehm, which first appeared in 1864, has been thoroughly revised and improved by the addition of recently acquired knowledge, under the editorial direction of Professor zur Strassen. It will consist in this—its fourth edition—of thirteen volumes, with about two thousand figures in the text, more than five hundred colored plates, etchings, and wood cuts, and thirteen maps.

The editor's preface gives so much valuable information concerning the new form of the great Natural History of Animals, that we present it herewith in English.

"When the Bibliographic Institute first proposed to me several years ago that I should prepare a new revised edition of Brehm's Tierleben, my first impression was that the revision must be limited to the absolutely necessary changes. For with respect to 'Brehm,' like almost all German zoölogists, I have stood since my childhood in a relation of sincere affection, and I half felt that a 'bettering' of the honored and esteemed book in important points was impossible.

"In the revision it has been my primary aim—with the full approval of the publishers—to retain those features to which the 'Tierleben' owes its reputation: the fresh vitality and popular exposition combined, in the happiest manner, with wealth of content. But, on the other hand, it became clear to us that the process of bringing 'Brehm' up to date could not this time be limited to the introduction of new discoveries and the omitting of antiquated material, but that, modification of the general plan in numerous important points was unavoidable. Above all, that the great acquisition of our time, the theory of evolution, must be emphasized more strongly than previously. Even externally, instead of the descending series, that order must be chosen which, beginning with the simplest organisms, leads upward to the highest. In the text, moreover, reference should be made to the descent and blood-relations of animals wherever they may be determined with sufficient certainty. On this account it seemed necessary, to a greater extent than previously, to describe the structure of animals and the functions of their inner parts. For with the greater extending of naturalistic knowledge even the public has become more familiar with this aspect of animals. Rich additions in the way of anatomical illustrations, in which the work formerly was almost entirely lacking are provided.

"And finally, there is still another important point: Animal Psychology. In the old 'Brehm' mention was often made of the 'feelings' of animals, and especially of mammals and birds; of their 'loves, hates, and fears'; and what they do instinctively was referred, without much thought, to their 'intelligence' and

<sup>1</sup> Brehm, Alfred E.: Tierleben. Allgemeine Kunde des Tierreichs. Vierte, vollständig neubearbeitete Auflage, herausgegeben von Prof. Dr. Otto zur Strassen. Leipzig und Wein, Bibliographisches Institut. 1911. (13 Bände in Halbleder gebunden zu je 12 Mark.)



their 'reason.' This is not a severe reproach to Alfred Brehm when one remembers how general, at that time, was the humanizing of animals, even among scholars. Nor is it to be regretted for Brehm's brilliant success in winning for the animal world that cordial interest of readers, most of whom had never troubled themselves about it before, was certainly due in large part to this very humanizing. Nowadays we know, that with the intelligence of animals in doubtful status, almost all of their wonderful performances can be explained in a simpler manner; by associated impressions of the circumstances accompanying their favorable and harmful experiences, or mostly even as inborn instincts. And since even now we do not know any means of judging about the 'feelings' and other mental processes of animals, it is better to remain silent concerning them. This modern point of view must be taken as the basis in a new edition of 'Brehm.' This is not equivalent to saying that the new 'Tierleben' will be any less sympathetic, or that the use of it by the laity, or even by children, will be less attractive; on the contrary, the wonderful purposefulness and perfection of the animal instincts, and the oftentimes amazing way in which apparently intelligent acts may be simply explained, probably will be more captivating for the present-day reader of 'Brehm' than the earlier humanizing.

"It therefore became clear that so far reaching a transformation as the one planned could not be effected by one person alone; the work must be divided. That delightful writer, the Director of the Zoölogical Garden of Berlin, Professor Ludwig Heck, undertook the revision of the 'Mammals,' which he knows so thoroughly. Professor (Doctor) William Marshall, the widely beloved author of '*The Walks of a Naturalist*'—who died in the midst of the task—turned over for the division on 'Birds' the rich material which he had been gathering for years toward a great ornithological work. For the 'Reptiles and Amphibians' the well-known specialist, Doctor Franz Werner, Professor in the University of Vienna was secured. 'Fishes' was undertaken by Doctor Otto Steche, privat docent at Leipzig, who has worked upon it at home and carried it with him in his journey around the world. Professor (Doctor) Richard Heymons of Berlin revised the volume 'Insects,' in which the spiders and millipeds are included. With each of these groups this scholar is thoroughly acquainted through his own investigations. The revision of the remaining 'Invertebrates' I undertook myself.

'Especial attention has been given to the illustrations—always a noted feature of the 'Tierleben.' In this it was worth while to take advantage of the modern processes of reproduction."

To condense the remaining page of the preface—no pains were spared to obtain accurate, realistic, and artistic drawings. Skilled artists were employed, who, in certain instances, made drawings from life in Africa, Asia, various parts of Europe, and England.

The new "Tierleben," of which at present the sixth volume, "Birds," has appeared, will stand as the authority among natural histories of animals. It is highly desirable that it be translated into English.